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WITH ABSTRACT OF THE LITERATURE

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Cadmium Poisoning: I. The History of Cadmium Poisoning and Uses of Cadmium

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THE JOURNAL OF INDUSTRIAL HYGIENE

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CONTRIBUTION TO THE METHODS USED FOR RAPID DETERMINATION OF DUST IN AIR*

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WHEN attempting to determine the dust content of the air, one is immediately faced with the selection of the method to be employed. That this question has not yet been satisfactorily solved is evidenced by the fact that a number of different methods have been suggested. Among these, the principal ones which have found practical use are the following:

1. *Counting* by microscope the dust particles which have fallen upon, or been impinged upon plates either uncoated or coated with some dust binding medium (*e.g.*, vaseline, oil, or gelatin), or which have been absorbed by water (as in the Palmer apparatus and the impinger).

2. *Weighing* a quantity of dust collected in some dust absorbing medium (*e.g.*, sugar, cotton, filter paper, or water).

3. Determination of the intensity with which the dust particles *refract, reflect, or transmit light* (photometric methods, such as the Tyndall method).

4. *Counting dewdrops* which have been condensed around dust particles (as with Aitken's apparatus).

5. Determination of particles that have been precipitated *electrostatically*.

Several sources of error and defects attach to all these methods. I shall not enter into a detailed criticism of these, but shall confine myself to pointing out only the most important:

1. The results with the first method vary with the magnification of the particles, the ability of the observer, and the difficulty of distinguishing between the light refracting particles in the dust binding medium and the grains of dust absorbed.

2. Since the weight of the absorbing agent is much greater than that of the dust particles, the weight of the dust is dependent on variations in the weight of the absorbing agent (*e.g.*, cotton wool, filter paper), and also on the degree of moisture absorbed

* Received for publication Jan. 15, 1932.

from the air during weighing, and on the sensitivity of the balance. When the absorbed dust is weighed after the absorbing agent is dissolved (for example, sugar in water), the insoluble matter which the agent always contains influences the result (even if a check test is made).

3. The photometric method may be affected by gaseous substances in the air, and by the size, dispersion, and color of the dust particles.

4. Condensation of water occurs around large molecular gaseous particles and ions in Aitken's apparatus, as well as around dust particles.

5. Testing aerial dust by electrostatic precipitation requires complicated apparatus.

In addition, mention should be made of the fact that the methods based on an investigation of minute quantities of air (*e.g.*, Aitken's method) are more liable to errors through temporary changes in the dust content of the air than are those based on a determination of the dust content in a larger volume of air (1).

The selection of a suitable method for dust determination is often difficult. If the investigation or research is to be thorough and exhaustive, preliminary tests may be made in order to determine which methods give the best results for the purpose. In simpler investigations, which are intended only to give a satisfactory idea of the dust content of the air from a practical point of view, a method must be selected which does not require expensive apparatus or involve troublesome and complicated processes. Following is a method which it has been shown by extensive check tests overcomes these drawbacks satisfactorily, and which at the same time is easy to carry out.

With the aid of a water driven pump, or other suitable suction pump,[1] air is aspirated through a glass tube down into the bottom of a small dust absorbing test tube of suitable shape (Fig. 1a). The tube is half or two-thirds filled with glass pellets 3 to 4 mm. in diameter, on top of which are placed a number of larger pellets to keep the small ones from being lifted by the passing air. The tube, together with the glass pellets, is coated with a thin layer of olive oil.[2] As the aspirated air passes through the layer of pellets, dust particles are absorbed by the oil. With this device air can be aspirated at a comparatively high speed (from 3 to 5 cu.m. an hour) with complete absorption of the dust.[3] The quantity of air aspirated is measured with the aid of a gasometer or some similar instrument.

For investigating and testing the dust content in street air and living rooms, from 10 to 30 cu.m. of air should be passed through the tube; for determinations in dusty factories and workshops, from 1 to 10 cu.m. are required.

After the aspiration of air is finished, the test tube is filled with ether and shaken. The suction tube is then

[1] Aspiration of air by a water pump requires a water pipe. In places where there is none, the vacuum pump of an automobile can be used by attaching the suction pipe of the pellet tube to the suction pipe of the vacuum tank of the automobile.

[2] This is best done by pouring the oil into the test tube containing the pellets, so that all the pellets are oiled; the surplus oil is then drained off by turning the tube upside down for a while on clean paper.

[3] By check tests in dust filled air with two or three pellet tubes one after the other, it has been proved that all measurable dust is absorbed in the first tube.

moved, and the ether and the pellets re poured off into a small funnel (Fig. 1b), on the bottom of which is placed an uneven piece of glass (for example, a piece of broken glass tubing) to keep the pellets from pass-

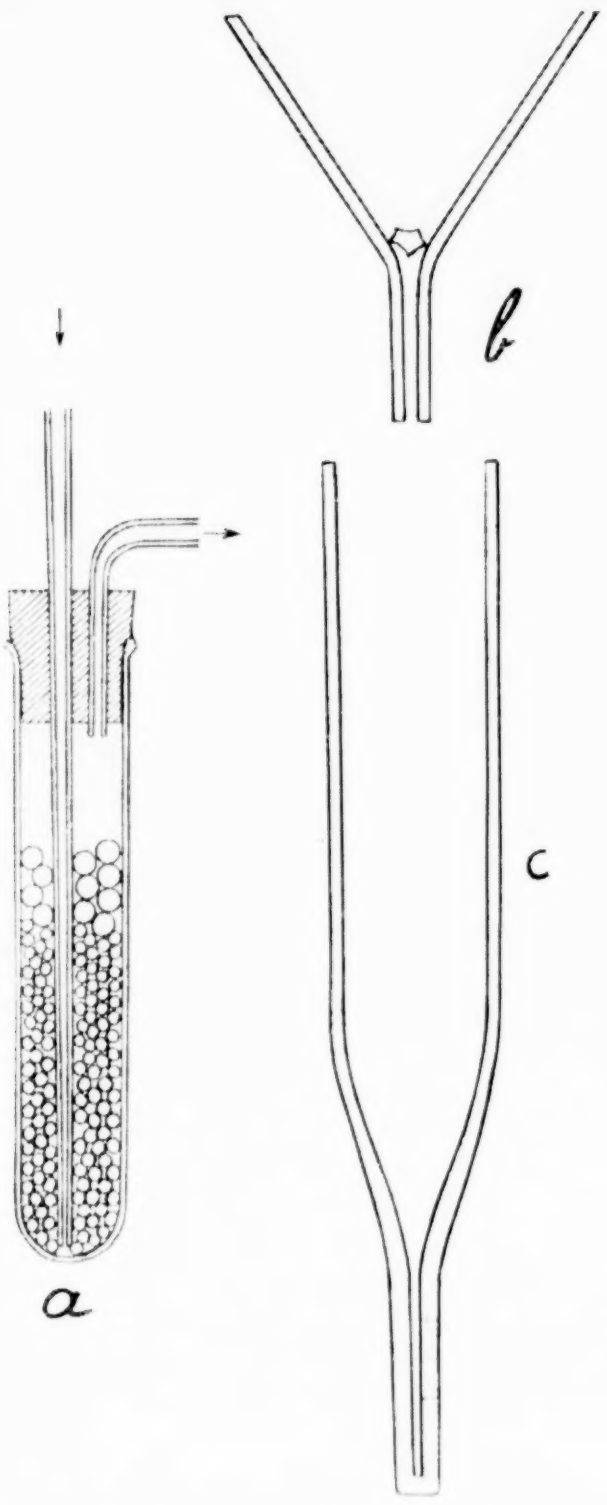

FIG. 1.—Showing pellet tube (about 15 by 150 mm.), funnel, and centrifuge tube used in method proposed for rapid determination of dust in air.

ing out of the funnel. The ether is collected in a centrifuge tube (Fig. 1c), to the bottom of which is attached a thick-walled capillary tube 1 mm. in inside diameter and 2 cm. or more in length. The test tube and the pellets are washed in this way four or five times. Check tests have proved this to be quite sufficient for washing off the dust particles absorbed by the layer of oil.

After washing is completed, the ether is strongly centrifuged, and the height of the centrifuged dust is ascertained (possibly with the aid of a magnifying glass). Owing to the low specific gravity of the ether, centrifuging can be done comparatively easily. If, for some reason, it is difficult, the dust in the capillary tube can be compressed by slight pressure with a wooden pin or the like of the same thickness as the capillary tube. Centrifuging can then be repeated. This method of compressing the dust has been found to give satisfactory and uniform results.

In certain instances a slight portion of the dust may be dissolved in the ether, but as a rule the dust particles are less soluble in ether than in water, which is often used for absorbing dust from the air. In order to obtain an even bottom surface in the capillary portion of the centrifuge tube, a suspension of from 2 to 3 mg. of red lead (oxide of lead) in ether can be centrifuged before the test; this will adhere to the bottom of the tube, and the ether can then be poured off (2).

When centrifuging of the ether sample containing dust is finished, a further quantity of red lead may be added and centrifuged; during this process the lead, by its weight, presses on the column of dust and enables the upper surface to be more easily gauged. The height of the column of dust indicates the amount of dust aspirated with the air. The exact weight of the

dust can be determined as follows: A known quantity of the dust tested (for example, 5 mg.) is weighed and centrifuged with ether.[4] The height of the column of dust in the capillary tube is then determined. In this way it has been shown that each millimeter of the dust column in a capillary tube 1 mm. in diameter corresponds to 0.3 mg. in the case of dust from homes, to 0.5 mg. in the case of street dust, and to 1 mg. in the case of dust from cement factory premises.

After the investigation is completed, cleaning of the capillary tube is facilitated by the use of a fine metal wire with a slightly bent tip.

For routine work this method possesses several advantages, particularly in cases where the air contains fairly large quantities of heavy dust, as on factory premises. Because of the fact that the dust is completely absorbed in the pellet tube, even when air is drawn through at a very great speed, tests with large quantities of air can be completed in a comparatively short period of time. This eliminates occasional variations in the amount of dust and makes it possible to get a satisfactory average from one test. Moreover, the testing is easy to carry out, and the results recorded are not based on a subjective judgment. The method does not require great training or expensive apparatus and, what is more important, does not suffer from sources of error of a temporary or unexpected nature, which constitute the greatest drawback in several of the other methods. In thirty-eight investigations carried out with air from public premises, from courtyards, and from factory premises, it has been shown to give very satisfactory and even results. Samples taken simultaneously with several pellet tubes have yielded results which showed a variation of less than 10 per cent., and for the rapid determination of dust this must be considered very satisfactory.

[4] In factories and the like, this quantity of dust can be allowed to settle on large paper surfaces.

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PROCEDURE FOR ESTABLISHING OPTIMUM AIR CONDITIONS FOR LIGHT AND HEAVY WORK*

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THE atmospheric factor has only recently become one of the essential problems studied by hygienists and physiologists. Most researches in this field deal with those effects of high temperatures which upset the heat regulating centers and cause distinct functional disturbances in the heart, lungs, and other vital organs. Improvements in working conditions at high temperatures are usually secured by: (*a*) application of scientific methods to industrial processes; (*b*) adoption of suitable hours of work and rest pauses; and (*c*) improvements in environmental conditions by means of ventilation.

The present work does not touch on the question of the effect of high temperatures on the organism but deals with the study of atmospheric conditions which lie between the optimum comfort zone and the onset of disturbances in the heat regulating apparatus. Although these disturbances have no obvious pathologic manifestations, nevertheless they produce discomfort and fatigue, and cause reduction in output. Such a situation is quite common in industries, and therefore improvements in this direction constitute a problem of paramount importance.

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Indexes of Atmospheric Conditions

Among the indexes of atmospheric conditions in use at present are the norms of Hill, the effective temperature, and the norms established by the People's Labor Commissariat (published by the Building Committee of the Council of Labor and Defense).

Norms of Hill

Table 1 shows the figures for energy expenditure during various kinds of work which were computed by Hill from observations of Becker and Hämäläinen and deductions of Lusk. Having thus determined heat loss per square centimeter of body surface, Hill evaluated these data in terms of

TABLE 1.—ENERGY EXPENDITURE IN VARIOUS OCCUPATIONS (HILL)

OCCUPATION	HEAT LOSS	OPTIMUM H VALUE[1]
	millical./ sq.cm./ sec.	
Tailor	1.36	5.44
Bookbinder	1.72	6.88
Shoemaker	1.81	7.24
Carpenter	2.1–2.51	8.4–10.04
Metal worker	2.31	9.24
Painter	2.44	9.76
Stonemason	3.86	15.44
Man sawing wood	4.62	18.48

[1] Value required to prevent perspiration.

kata-thermometer readings by assuming that the loss of heat from the dry kata is four times as great as that from the surface of man's skin. According to the cooling powers (H) recommended by Hill, the optimum temperature for a metal worker should be 2.4°C. in still air, that for a stonemason −21°C., and that for a man sawing wood −31.5°C.

Is it thus that we must prevent sweating? Can we propose such optimum conditions? These questions show that it is impossible to evaluate sensations of comfort from kata-thermometer readings. Moreover, it must be remembered that under certain circumstances, corrections have to be applied to the readings of the kata-thermometer, as has been pointed out by Hill and others.

With air movement and different air temperatures the coefficient 1:4 varies. Whereas the value H is determined from a mean kata temperature of 36.5°C., the skin temperature does not remain fixed. It falls, for instance, as a result of air movement, and approaches the environmental temperature (which is usually lower than skin temperature), so that the loss of heat from the body surface proceeds more slowly. In order to avoid discrepancies, Hill proposed a formula which takes the skin temperature into account:

$$H_2 = H_1 \frac{\theta_2}{\theta_1}$$

where H_2 = corrected kata cooling power at skin temperature
H_1 = dry kata cooling power
θ_2 = difference between cheek and air temperature
θ_1 = difference between mean temperature of body (36.5) and air temperature

This correction complicates considerably the determination of the actual kata cooling power, and makes the expediency of this method questionable, since preliminary physiologic observations are necessary.

There is still another difficulty when using the kata-thermometer in connection with tables of H values for different conditions. The measurement of kata cooling powers in moving air is liable to unavoidable errors. The highest H readings are obtained when the kata bulb is at right angles to the air current (this has been proved in our laboratory), and it was under these conditions that Hill worked out his data. In all other positions of the bulb, the readings are considerably lower (as much as 50 per cent., according to our data). Under ordinary industrial conditions air currents change their direction, and it is difficult or impossible to fix the bulb of the kata exactly at right angles to the air flow. Finally, we must remember that Hill's values apply to Englishmen—people of another land, whose habits and methods of work are different from ours; therefore these data require verification under our particular living and working conditions.

Effective Temperature Norms

The effective temperature index, which has been determined from sensations experienced in different combinations of temperature, humidity, and air motion is applicable to Americans. We may suppose that subjective sensations of warmth and cold under similar atmospheric conditions would be different for an American than for a Russian; therefore we

cannot accept this American index unreservedly. Moreover, the American effective temperature index has been determined for rest and light physical work. No data are given as to the equivalent combinations of temperature, humidity, and air movement for heavy physical work. Finally, the factor of acclimatization has not been taken into account. The subjects passed from a room with one set of air conditions into another with a different set in but a short period of time, and the sensations of warmth were registered immediately.

Norms of People's Labor Commissariat

The norms of the People's Labor Commissariat, published in 1929, were computed from contemporary available data. According to these norms, for light manual work (assemblage, gluing, sorting small objects, etc.) the temperature of the workroom must be kept at from 17° to 20°C. For heavier work (such as operations on metal working machines) the temperature should be from 15° to 17°C. For work requiring considerable expenditure of muscular energy (such as carrying loads, hammering, etc.) it should be from 12° to 15°C. The relative humidity must not exceed 70 per cent.

In this part of the norms correct indications as to suitable temperatures are given and they are supported by the findings in the present study. The second part of the norms, however, comprises defective indications. In industrial processes requiring excessive heat and humidity, the norms recommend the following combinations of temperature and humidity:

Temperature °C.	*Relative Humidity* %
25	70 or less
26	60 " "
27	50 " "
28	35 " "
29	25 " "

When these combinations cannot be maintained—that is, when the temperature and humidity are higher than is indicated—it is proposed to increase air movement in order to secure the most favorable conditions. No recommendations are made concerning air velocities and methods for obtaining desired air movement, except that the effective temperature must not exceed 23°C.

This second part of the norms of the People's Labor Commissariat requires correction. The data are not confirmed nor are they accurate according to the present investigation.

This brief review of the existing thermic norms and tables convinces us of the need for establishing in our Union our own comfort zones—that is, those air conditions under which the organism can best adapt itself to its industrial environment.

Optimum conditions vary with the occupation, according to the type and rate of work. To establish a comfort zone for each profession separately would be an extensive task; therefore we have undertaken for the present the more general problem of establishing optimum conditions for light and heavy work in general.

Heat Regulation in Man

We know that heat loss takes place chiefly through the skin by convection, radiation, and evaporation. Under normal conditions heat loss by con-

vection and radiation amounts (according to Rubner) to 75 per cent. of the total loss by the skin surface; loss by evaporation amounts to about 21 per cent. These proportions may, however, show wide deviations in cases of considerable heat production (heavy work) and in cases of high environmental temperature. In such instances, loss of heat by radiation and convection may be impossible and the entire loss may take place by evaporation.

For comfort, heat production and heat loss must be properly balanced. Within the comfort zone, this balance is secured without any strain on the heat regulating mechanism. When the external temperature rises above the limits of the comfort zone, a strain is imposed upon the heat regulating center in order to maintain the body temperature and to prevent an excess of heat production and heat storage in the organism. This strain on the heat regulating mechanism is an act of self-defense on the part of the organism, without which it would be impossible to perform heavy work or endure exposure to high temperatures. Habitual exposure to high temperature produces a strain on the nervous system, on the heart, and on the organs of secretion.

The skin is the first to be affected by external factors. The nerve endings, sensitive to heat and cold, transmit these stimuli to the heat regulating center which in turn causes dilatation of the cutaneous vessels and increased flow of blood through them. This increased blood supply results in a rise in skin temperature and hence in greater heat loss.

German and English workers point out the direct relationship between skin temperature and environmental temperature. Rubner (1) gives the following correlations:

Air Temperature	*Skin Temperature*
°C.	°C.
10.0	29.0
15.0	29.2
17.5	30.0
25.6	31.7

The essential points in all previous work are (*a*) that *until perspiration sets in*, the skin temperature runs parallel to heat sensation; and (*b*) that a definite subjective sensation of warmth or cold corresponds to a definite skin temperature—that is, skin temperature represents an objective index both of the thermal effect and of the subjective sensation.

The effect of wind on skin temperature has been investigated by Rubner (2), Lange (3), Kisskalt (4), Liese (5), and others. Within the temperature range which we are at present studying, the cooling power of the wind is explained by the increase in heat loss which it produces by renewing constantly the air in contact with the skin. This new air, being lower in temperature than the skin, increases heat loss by convection. Heat loss by evaporation is also increased, as the new air is less saturated with moisture than that directly adjacent to the skin. Data collected in our laboratory (6) have established the fact that clothes, as well as the direction of the air current, play an important part in the effect of air motion. The effect of moisture is greatest at higher environmental temperatures (26° to 28°C.).

It has been shown that man experiences a sensation of comfort in air

onditions under which his skin temperature remains within certain limits. These limits differ somewhat in the findings of various authors, but on the whole they are in fairly close agreement. According to Marschak, the normal range of skin temperature on the chest of a man at rest is between 31.5° and 33.5°C. As long as the skin temperature remains within these limits, the subject feels comfortable—neither hot nor cold. With every rise or fall outside these limits, he experiences discomfort (warm to hot, or cool to cold).

Experimental Study

Methods

In order to determine optimum air conditions, we have observed two types of work, one light and the other heavy, over a long period of time and under a variety of air conditions.

It is possible to determine objectively whether any given air condition constitutes that optimum at which the skin temperature keeps within its normal limits, or how much it deviates from the optimum. A new optimum may then be established by varying the temperature, humidity, and air movement. For determining the optimum air conditions for light physical work, the skin temperature method seemed quite promising and therefore we adopted it. In the case of heavy muscular work, however, the skin temperature ceases to be a proper index, because it falls as a result of the evaporation of water. Marschak (7) has shown that under such circumstances a redistribution of blood takes place, and consequently the skin temperature rises in certain parts of the body and falls in others, regardless of the environmental air conditions.

Since under these conditions the skin temperature can no longer be regarded as a thermal index, and since in heavy work the sweat glands are involved in heat regulation, we decided to observe the stages of perspiration during heavy work. We assumed that the more trying the air conditions, the sooner perspiration would set in and the more profuse it would be. For our observations, we used W. L. Minor's[1] method. According to this procedure, the forehead (or other part of the body where one wishes to observe perspiration) is covered with a thin coat of a mixture consisting of iodine, alcohol, and castor oil, and powdered with rice starch. When perspiration sets in, a reaction between the iodine and the starch takes place in the pores of the skin, and dark brown dots appear. At first these dots are minute and few in number, but as perspiration increases and more glands come into play, the number of dots increases and they run together, forming larger dots, then spots and patches; finally the entire forehead becomes black, drops of sweat run faster and faster, and the starch is washed away. Observing the perspiration on the forehead in this way, one can differentiate the following stages: (1) separate dots; (2) large dots; (3) spots and dots; (4) small patches; (5) large patches, confluence of patches over the entire

[1] We are greatly indebted to Dr. Minor, who gave us a detailed explanation of the method of registering the stages of perspiration which he has worked out and made use of in a series of studies on nervous pathology.

forehead; and (6) profuse washing away of starch. (See Fig. 1.)

When air conditions are not suitable (for example, 32°C. without air movement), these stages follow one another in rapid succession; the dots appear a few seconds after the experiment has begun, and a few minutes later all the other phases are completed. Under favorable conditions (13° to 14°C.), the first dots appear from thirty to thirty-five minutes after the experiment has begun and they increase in number very slowly.

FIG. 1.—Stages of perspiration. 1 = separate dots; 2 = large dots; 3 = spots and dots; 4 = small patches; 5 = large patches, confluence of patches; 6 = starch profusely washed off.

In our study we have established the fact that at every given phase of perspiration the subject experiences a corresponding sensation of warmth. Before perspiration sets in and with the appearance of the first dots, he feels comfortable—neither hot nor cold; during the second and third phases he is warm, but pleasantly so; at the appearance of spots, a sensation of discomfort sets in, progressing from warm to very warm, hot, oppressive, and stifling. Just as skin temperature demonstrated objectively the subject's sensations of warmth during light work, the objective picture of perspiration on the forehead reflected his sensations during heavy work. Air movement affects the stages of perspiration in the same way that it affects skin temperature during light work. Therefore in establishing optimum air conditions for heavy work, we can resort to the method of observing the stages of perspiration for an objective evaluation of the suitability of given conditions and also for their correction, if desired, until a new optimum is established at which the picture of forehead perspiration remains within the limits of the third stage—that is, the stage of spots.[2] Under this

[2] These stages were established on the basis of data obtained from our own experi-

condition the organism makes strenuous efforts to prevent overheating, through the action of the heat regulating mechanism: (*a*) by an increase in skin temperature and (*b*) by an increase in perspiration, both of which lead to greater heat loss. We have, for the most part, followed these two methods in our research.

In selecting experimental subjects we have taken into account only the energy expenditure characterizing the work, since this is the factor controlling heat production and heat loss. For light physical work we have chosen as subjects seamstresses working on motor sewing machines, whose energy expenditure represents 500 c.c. of oxygen per minute. Our heavy physical work consisted in raising weights, corresponding to a working rate of 14,500 kg.m. per hour and an energy expenditure of 930 c.c. of oxygen per minute.

Data and Results

Light Physical Work

In our laboratory we equipped a small experimental room with two sewing machines and a motor with suitable pulleys, for changing the speed. The seamstresses received standard materials from the factory—sheets and pillow cases—and returned finished goods. The working schedule was the same as at the factory, but the hours were shorter: two hours of work, a ten-minute rest pause, two hours of work, dinner (half an hour), and two hours of work. In the course of our experiments we passed from six observation hours to four, as this change produced no essential variation in the physiologic reactions. Observations were made three or four times a day: in the morning after an hour's rest; sometimes one hour later; after two hours' work; and before dinner—that is, after four hours of work. In the six-hour experiments, observations were also made at the close of work.

Skin temperature was recorded with a resistance thermometer[3] and was taken in the morning when the subject was at rest before beginning work, sometimes one hour later, after two hours' work, and at the end of the working day. The readings were taken on the forehead and the sternum, and in some experiments, on the back. Our standard records included two areas: the forehead, always uncovered; and the sternum, covered by a light cotton blouse (more or less standard clothing throughout the experiment). We proceeded on the following principles (Winternitz, Rubner, and Heymann): From the thermal reaction of one point on the skin's surface one may judge more or less the vasomotor activity of the whole body; and from the temperature of one uncovered area or one covered area, one may judge the temperature, respectively, of all uncovered or covered areas (taking into consideration, of course, type of clothing). Opinions differ as to the stability of forehead temperature. Reichenbach and Heymann (8) consider the forehead as the

ments; we have no evidence on this question from the literature.

[3] In industrial conditions the ordinary glass chemical thermometer answers the purpose; to protect it from radiant energy and wind, a small screen has been introduced.

best point for observing the effect of heat on the skin. At the same time, their theoretical arguments speak to the contrary: "The forehead is less affected by physiologic reactions than other parts of the head. . . . . The forehead approximates more or less the condition of dead skin." In our experiments, however, we had to take into account physiologic effects—the influence of the work itself. Marschak (6) notes that the temperature of the forehead and cheeks in male experimental subjects is often affected by wearing a hat, shaving, etc.

Differences of opinion exist also concerning the relative stability of temperature of covered and uncovered areas. Rubner states that the temperature of uncovered parts of the body is more variable than that of covered parts, whereas Lange affirms that covered areas usually react more than uncovered, owing to deficiency in the heat regulating mechanism.

In order to be able to judge the status of heat regulation of the entire body more accurately, we decided to record the temperatures of a covered and an exposed area. In our experiments, observations on the women operatives gave similar curves for the skin temperature of both forehead and sternum. Our data demonstrate that in still air, skin temperature follows closely the room temperature. In Table 2 are given the daily average values for the forehead and sternum of subject P, in still air between 18° and 28°C. It can be seen that the rate of increase in skin temperature is not quite uniform with the rate of increase in environmental temperature within the range of 18° to 22°. This has also been noted by Kisskalt (4), who believes that skin temperature begins to rise in close correspondence with environmental temperature after the latter has reached 23°.

The subjective sensations of the operatives employed in the experiments follow closely the skin temperature (Figs. 2 and 3). The comfort zone for one subject was found to be from 32° to 35°C. according to forehead temperature, and from 31° to 34°C. according to sternum temperature. The comfort boundaries of another subject were from 0.2° to 0.3° higher. Values of skin temperature according to other authors are as follows:

TABLE 2.—AVERAGE FOREHEAD AND STERNUM TEMPERATURES IN SUBJECT P AT DIFFERENT ROOM TEMPERATURES

ROOM TEMPERATURE	AVERAGE RELATIVE HUMIDITY	SKIN TEMPERATURE	
		Forehead	Sternum
°C.	%	°C.	°C.
18	40–50	33.0	32.8
20	"	34.0	34.0
22	"	33.9	33.9
24	"	34.9	34.9
26	"	35.1	35.2
28	"	35.8	35.6

	°C.
Kisskalt	31.5–33.5 (sternum)
Rubner	32.0–33.0 (nearer 33)
Kunkel	32.0–35.0
Cobet	32.0–35.0
Marschak	31.5–33.5

When air movement was produced by a special ventilating equipment (Fig. 4), it was possible, even in comparatively high environmental temperatures, to reduce the skin temperature to a degree which was found to be the most pleasant in experiments in still

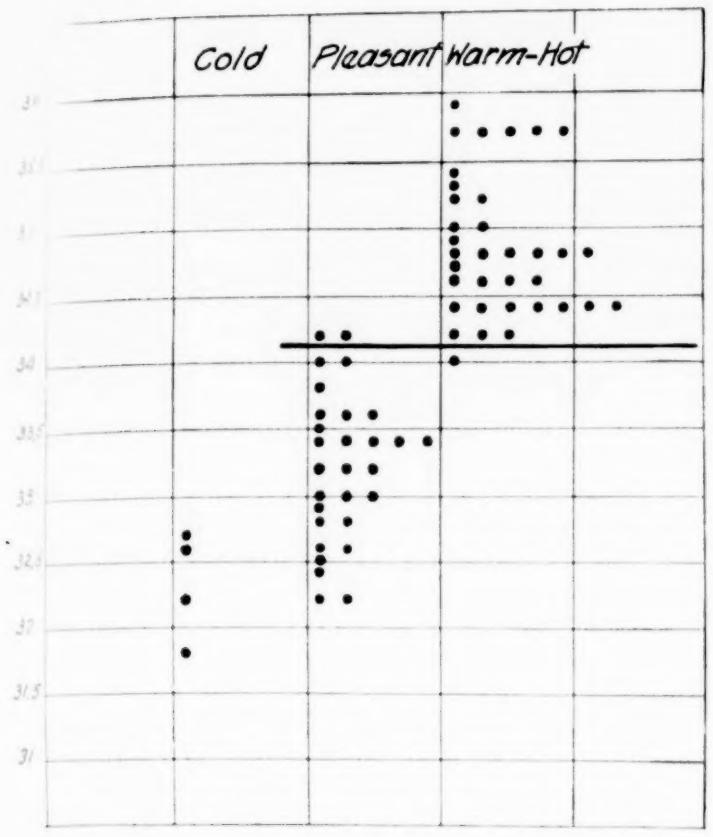

FIG. 2.—Skin temperature on forehead immediately after light physical work at uniform cooling power.

Dots represent warmth sensations of subject.

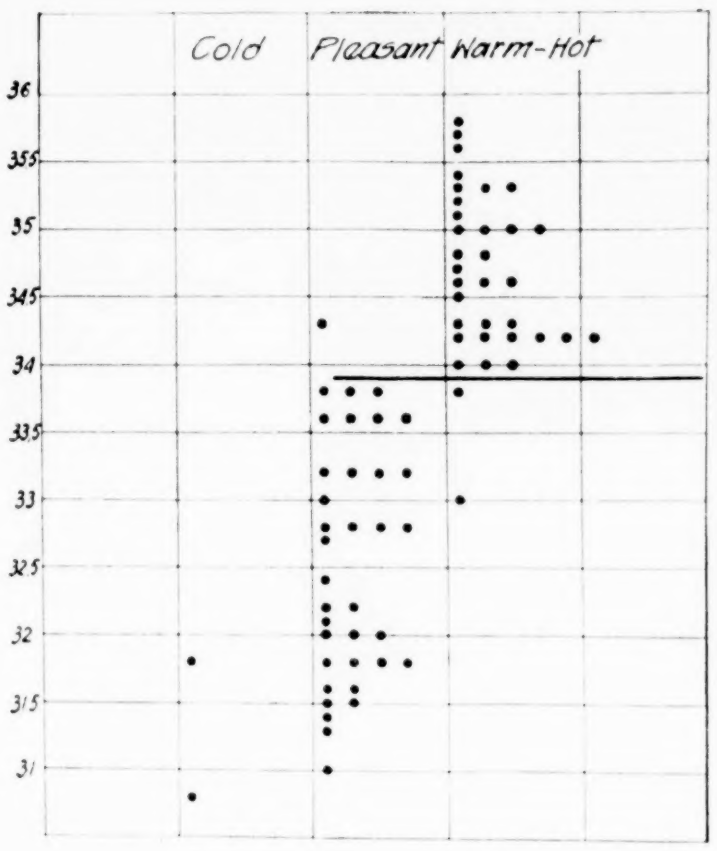

FIG. 3.—Skin temperature on sternum immediately after light physical work at uniform cooling power.

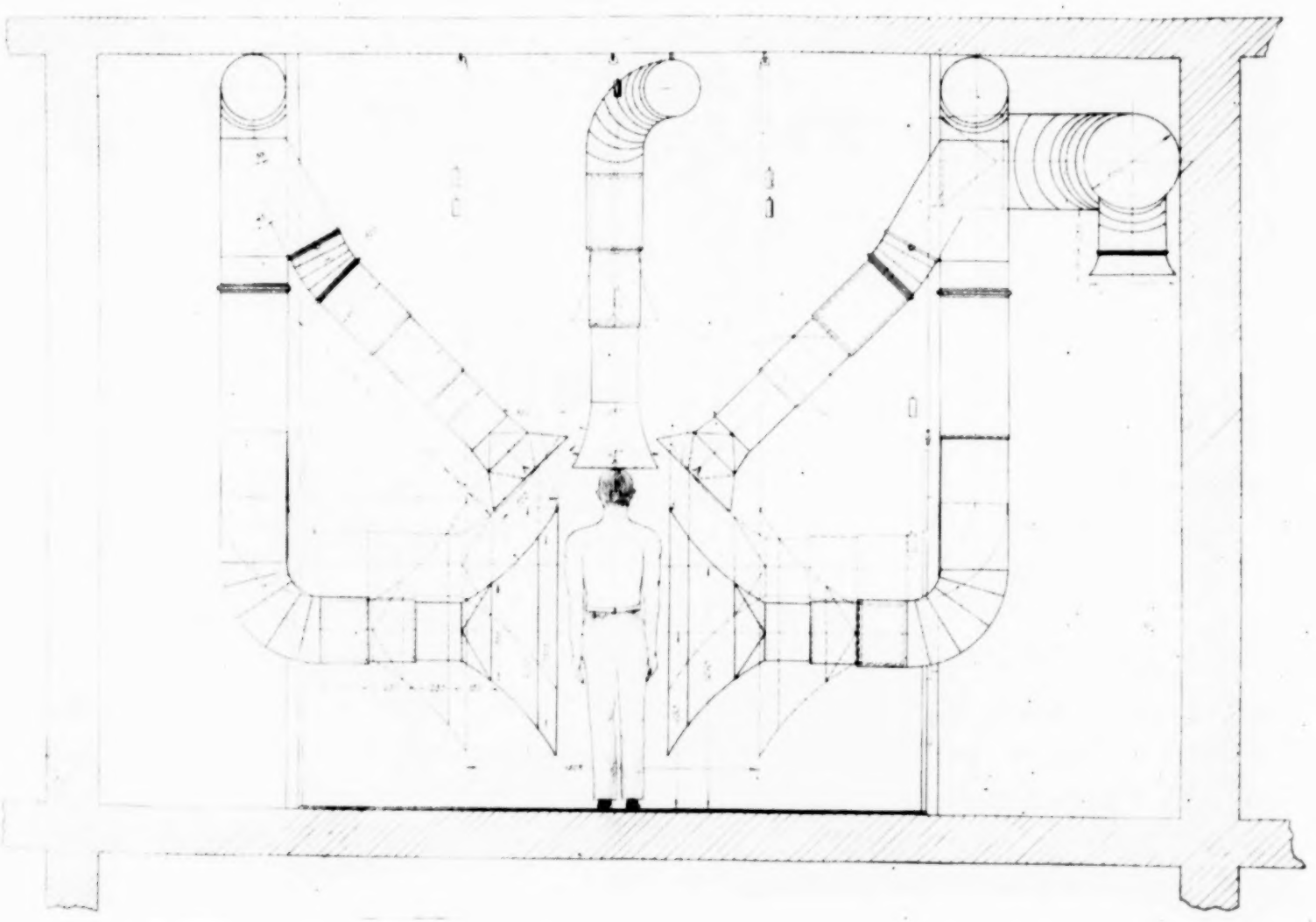

FIG. 4.—Ventilation equipment in experimental room.

air. Correspondingly, the subject's sensation of warmth during work changed from unpleasant, oppressive, and stifling to a pleasant one.

Figure 5 shows records of skin temperature taken on the forehead, sternum, and back with room temperature at 26°C., moderate humidity, and with still and moving air. The cooling effect of air motion lowered the temperature of the skin to within its normal limits. Figure 6 shows that air velocities of 100 to 150 meters per minute are inadequate; the skin temperature falls, but it still remains above 34°.

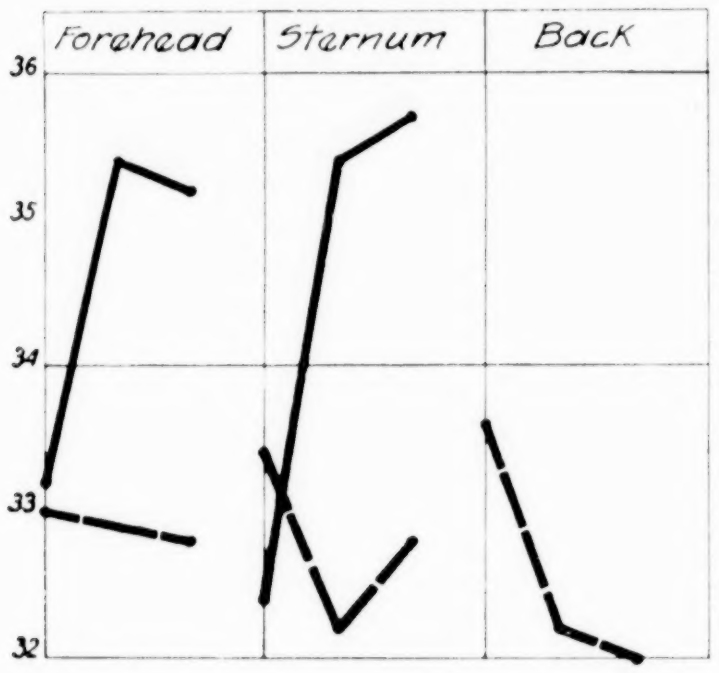

FIG. 5.—Skin temperature on forehead, sternum, and back during light physical work at a room temperature of 26°C.

Solid line = without air movement; broken line = with air moving at a velocity of 80 to 85 meters per minute.

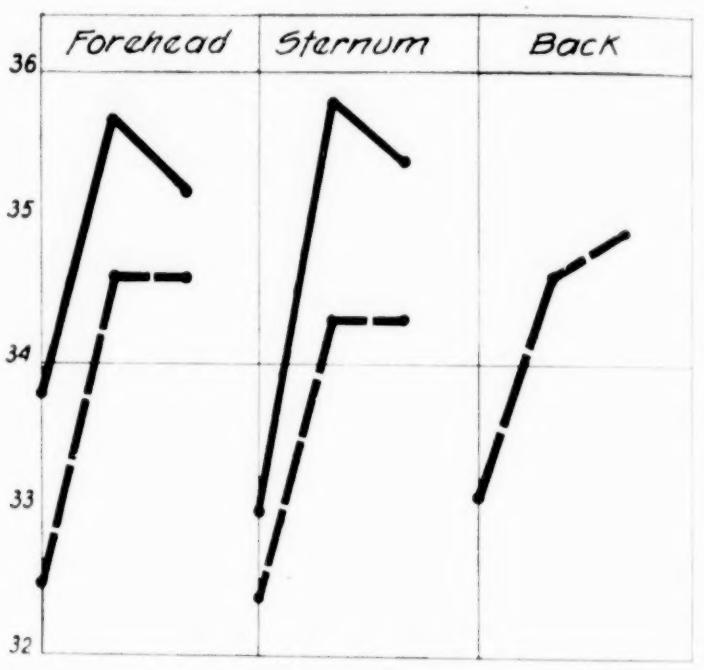

FIG. 6.—Skin temperature on forehead, sternum, and back during light physical work at a room temperature of 30° to 32°C.

Solid line = without air movement; broken line = with air moving at a velocity of 100 to 150 meters per minute.

Great care must be taken to keep the air around the subject at a uniform velocity so that its action will be efficient and pleasant. When air motion was uniform, we found no discrepancies between the records of skin temperature on the forehead, sternum, and back and the subjective sensations of the operatives under observation. Our data differ from those of Heymann and Korff-Petersen (9), who found that forehead temperature does not change in accordance with the different sensations of warmth experienced during various air velocities. When the velocity of the air current exceeded 90 to 100 meters per minute, it produced unpleasant sensations and also hindered work by blowing about the material which was being sewed.

From these data on skin temperature and on subjective sensations of the operatives, we have established the optimum air conditions for light work. These are presented in Table 3. Other physiologic reactions, such as temperature, pulse, and blood pressure, showed only slight variations, and it was difficult to establish any definite relationship to atmospheric temperature. Air movement, however, affected the degree of the reactions to some extent. Thus, in

still air the average increase in pulse rate after work was 4 beats, and the average rise in body temperature 0.25°C. In experiments with air movement at the same room temperature, the average pulse rate was increased by 0.9 beat and the average body temperature by 0.1°C.

TABLE 3.—OPTIMUM AIR CONDITIONS FOR LIGHT PHYSICAL WORK

DRY BULB	RELATIVE HUMIDITY	AIR VELOCITY	REMARKS
°C.	%	*m./min.*	
18	40–50	.....	.....
20	"	10–15	One hour after beginning work.
22	"	20–30	.....
24	"	50–60	.....
25	"	70–80	.....
26	80	80–90	.....
28	40–50	100	Cooling power not absolutely effective;
	70	...	decided improvement noticeable.
30–32	50	...	Not improved by air velocities of 100–150 m. per min.

TABLE 4.—OPTIMUM AIR CONDITIONS FOR HEAVY PHYSICAL LABOR

DRY BULB	RELATIVE HUMIDITY	AIR VELOCITY	REMARKS
°C.	%	*m./min.*	
13–14	40–50	....	Pleasant in still air.
18–19	"	35–40	At beginning of work, 15–20 m. per min.
20	"	60–70	.....
22	"	70–80	.....
24	"	80–90	.....
24–25	80–85	....	Not improved by air velocities of 90 and 115 m. per min.
26	40–50	120–130	.....
	80	....	Not improved by air velocities of 120–150 m. per min.
28	40–50	130–140	Not absolutely effective; decided improvement noticeable. Conjecturally, 150–170 m. per min. are required.

Heavy Physical Work

In our experiments heavy physical work consisted in raising and lowering a 16-kg. weight. Each subject was required to raise and lower the weight twenty times each minute; thus the mechanical work represented 14,000 kg.m. per hour. According to Rubner's classification, this work requires a great expenditure of muscular energy. In the first series of experiments the work was carried on for two hours, and in the second series for four hours. No essential differences were recorded in these two series.

The working schedule included frequent rest pauses, as is the case under industrial conditions when heavy work is performed. The subjects—two men—worked ten minutes with a rest pause of from two to five minutes. In order to check the data, in some of the experiments we required longer spells of continuous work—from thirty-five to sixty minutes.

Before the subjects entered the experimental room, the skin of their foreheads was treated according to Minor's method. During the experiment, observations on the stages of perspiration and on the warmth sensations of the subjects were recorded every five or ten minutes, and sometimes oftener. By means of air movement we have been able to produce optimum air conditions as shown in Table 4, according to perspiration and subjective sensations of comfort. Here also, as in the case of light work, the effect of air motion on other physiologic reactions such as body temperature, pulse rate, and gaseous exchange was observed, but it was impossible to establish any definite correlation between the degree of response and the environmental temperature. A marked effect became apparent only when the air temperature rose to 31° or 32°C.

The frequency of the heart beats rose immediately after work was begun (after ten seconds). In experiments with still air at temperatures from 14° to 28°, it increased 30 beats per minute; with air motion at temperatures from 18° to 28°, it increased 20. In still air at 32° the increase was 55 beats; at the same room temperature with air velocities of 130 to 180 meters per minute, it was 37 beats. The pulse returned to normal very rapidly—in from two to four minutes—in all the tests carried out at temperatures ranging from 13° to 28°. At 32° it required half an hour or more to return to normal.

The average values for lung ventilation and gaseous exchange were, respectively, as follows: in tests in still air, 24.3 liters and 935 c.c. per minute; in moving air, 23.6 liters and 894 c.c. per minute. The body temperature rose immediately after work; in still air the increase averaged 0.3°C., and in moving air 0.03°C. When the room temperature was 32°, the average increase was 0.7° in still air, and 0.4° in moving air.

Comparison of Data with Kata and Effective Temperature Indexes

We have compared our data on subjective sensations, skin temperature, and perspiration with the kata cooling power and effective temperature indexes. Our comfort zone for light work lies within the range of H = 4.5 to 5 in still air tests, and within the range of H = 6 to 7.5 in tests with moving air (H values were calculated from Hill's formula). The optimum values for H differ for conditions with air movement and for those with still air. The same is true of the effective temperature index. The comfort zone lies between 16° and 18° effective temperature in still air, and between 16.8° and 22.7° in moving air.

Our comfort zone for heavy physical work does not always coincide with that of the kata and effective temperature. Discrepancies occur between subjective sensations and stages of perspiration on the one hand and

H values and effective temperature on the other. Thus effective temperatures[4] of from 12° to 14° in still air and from 16° to 18° in moving air correspond to a sensation of comfort. Effective temperatures above 19° are as a rule associated with sensations of discomfort, although in four cases out of forty-six this was not the case: effective temperatures of 19.4, 19.9, 20.6, and 20.9 were acknowledged subjectively as comfortable, and were attended by corresponding "permissible" stages of perspiration.

Calculating the value of H (by means of Hill's formula) in thirty-six cases with still air, we observed a certain correlation between subjective sensations and this value. The comfort zone lies between H = 6 and H = 6.5. In experiments with air movement, the calculated value for H corresponded in nine cases to the subjective sensations and to the stages of perspiration; in sixteen cases there was not such close correlation (for instance, 5.3 = rather warm, almost pleasant; 7.2 = warm). In our table of optimum conditions the comfort zone according to kata cooling power lies between 7.5 and 10.5.

In moving air the wet kata cooling power showed no definite correlation with the cooling effect on the subject under examination (twenty-one cases). In experiments with still air a certain correlation was noted—namely, that wet kata cooling powers below 18 were associated with a feeling of discomfort.

Lack of close correlation between dry and wet kata cooling powers and sensations of warmth in man may be accounted for in several ways: The cooling rate of the kata in moving air is considerably greater than that of man; marked errors in kata readings, especially in moving air, are possible and often unavoidable; and finally, an analogy between the kata-thermometer and the human body cannot always be conceded.

Granting that the kata-thermometer (dry or wet) presents an analogy to a man at rest, it is difficult to believe that this is true for a man engaged in heavy work which calls into play the complex heat regulating mechanism. An analogy is usually assumed between the wet kata and a man perspiring. This does not, however, seem to be the case: Evaporation of moisture from the wet bulb of the kata sets in from the moment the kata begins to cool, and proceeds uniformly throughout. Perspiration in man never sets in all over the body at the same time; the skin at first is dry, then certain areas sweat, and perspiration gradually increases. With the different stages of perspiration heat loss naturally varies. Moreover, perspiration is produced and evaporated simultaneously. Thus it may be seen that in similar atmospheric conditions, the action of the wet kata differs considerably from that of the human body.

It is obvious that the closest approximation of the kata-thermometer to the human body is reached when a man is at rest in still air. The greater the energy expenditure and the more unusual the air conditions, the more difficult it is to establish a relationship between the kata and the human body.

As to the effective temperature

[4] Since there are no data on effective temperature for heavy physical work, we have calculated our data provisionally according to effective temperature for light work.

index based on sensations of warmth at rest or at light work, here also we must point to the more complex relationship existing between atmospheric environment and man's sensations when engaged in heavy work. All industrial processes involve periods of work interrupted by short, more or less frequent rest pauses. During these pauses, while heat production does not increase, heat loss remains at a high level owing to the increased cooling conditions of the atmosphere necessary for the work being performed. Under these circumstances the optimum should be set at the lowest limit of the optimum range which will permit rest pauses without sensations of cold (too great a cooling effect). This explains why our optimum conditions are relatively high (at least when expressed in terms of kata and effective temperature). This optimum allows heavy work to be carried on with comparative ease and without excessive perspiration, and yet does not prevent a feeling of well-being and comfort (warmth) during short rest pauses.

Summary

1. At environmental temperatures ranging from 14° to 28°C. in the absence of any local source of radiant energy, it is possible to establish "comfort" conditions both for light and for heavy work.

2. For determining the optimum environmental conditions for light physical work, the skin temperature is a suitable index.

3. For heavy physical work the optimum conditions can be established by observing the stages of perspiration.

4. Both sets of experiments emphasize the importance of air movement for a man at work as indicated by the principal physiologic reactions of the organism.

5. It is possible to make use of Hill's kata norms only for man at rest in still air. No analogy can be established between a man performing heavy work in still air and kata-thermometer indications.

6. In determining the comfort zone according to effective temperature, it is necessary to give two zones: one for the effective temperature with still air and another (always higher) for effective temperature with moving air.

7. The results of our observations will no doubt require correction when tested under actual industrial conditions. We have ourselves observed one correction which is necessary: During the first fifteen or twenty minutes of our experiments, when the organism is becoming acclimatized, our optimum is obviously too low and should be amended slightly either by a reduction of 15 to 20 per cent. in the cooling power or by the use of clothing, as for example, an overall or a blouse.

8. Further experiments are necessary to determine the possibility of using kata readings and effective temperature index, and to revise these indexes according to our own living and working conditions.

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CADMIUM POISONING: I. THE HISTORY OF CADMIUM POISONING AND USES OF CADMIUM*

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EXTENSIVE industrial use of cadmium is comparatively recent, although cases of cadmium poisoning were reported by Sovet (1) as early as 1858. It was not until after the World War and the introduction of cadmium plating that cadmium came into prominence industrially. The first work of importance on the toxic effect of cadmium was that of Marmé (2) which appeared in 1867, and since that time a number of investigators have published work on the problem. It is an interesting fact that although all the cases of industrial cadmium poisoning reported in the literature occurred through the respiratory system, all attempts to produce the condition experimentally in animals, with the exception of Otto's (3) work, in 1925, have been by oral administration of cadmium or by subcutaneous or intravenous injections. While these investigators present valuable information on the physiologic and pharmacologic action of cadmium and on the macroscopic changes induced by the metal, and in some instances give the distribution of cadmium in the body, their data are very incomplete from the standpoint of the industrial hygienist. With the exception of Severi's (4) investigations, in 1896, on the alterations in the kidneys due to cadmium, no microscopic study of the changes produced in the organism by this metal exists. As late as 1930, Schwarz (5), professor and head of the Division of Industrial Hygiene in Hamburg, concluded the presentation of a case of cadmium poisoning by saying that he was unable to state whether or not some of the lung conditions which occurred afterward were to be attributed to cadmium.

The aim of the present work is to summarize in some detail the existing data concerning cadmium, preliminary to a careful experimental study leading to the establishment of the pathologic changes which occur in cases of exposure to cadmium, especially through the respiratory system, and to recommendations for the prevention of cadmium poisoning.

EXPERIMENTAL CADMIUM POISONING

Cadmium occurs usually with zinc, and consequently in the literature the two metals are closely related. Up to 1817 no distinction was made between them. This is shown by Kopp (6) who gives the history of cadmium in his book on "The History of Chemistry," published in 1847, and also by Mellor (7), in 1923, in his "Treatise on Inorganic and Theoretical Chemistry."

The origin of the name cadmium is connected with the manufacture of

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bronze. In the book "On Marvels," attributed to Aristotle (320 B.C.), there is an account of the manufacture of bronze without tin, at Mossynoecia, near the Black Sea, by melting copper with a peculiar earth found there. The bronze produced was very glossy and of a bright yellow color. This earth-like substance was called "cadmia" by Dioscorides and Pliny (first century A.D.), a name which was also applied to the flue dust which collected in smelting furnaces. It is probably derived from Cadmos—son of Agenor, king of Phoenicia, and brother of Europa—who was the first to introduce the use of zinciferous earth at Thebes in Greece. This same zinciferous earth was also given the name "tutia," which is attributed to Zosimus, the alchemist, from Alexandria (fifth century A.D.). The persistence of these two names is noted in 1804 in a book by Fourcroy (8) in which he states that oxide of zinc, from zinc which has been sublimed and burned, attaches itself to the chimneys of the furnaces, forming grayish incrustations known in commerce as tutty, or cadmia of furnaces.

The discovery of the element cadmium was made by Stromeyer of Göttingen, in 1817, through the yellow tinge noted in a sample of iron free zinc carbonate which he attributed to a new element. Hermann of Schönebeck, in 1818, obtained a yellow precipitate with hydrogen sulphide in an acid solution containing zinc, and he also attributed this yellow precipitate to a new element. At the same time, Meissner of Halle confirmed Hermann's findings, and Karsten of Berlin discovered cadmium in Silesian zinc ores. Different names were proposed for the new element, but finally Stromeyer's proposal of cadmium, after "cadmia fornacum," was accepted.

Van Hasselt (9), in his book published in 1862, briefly mentioned cadmium oxide, and especially cadmium sulphate, as producing nausea and vomiting when given in small doses. He also mentioned an experiment made by Burdach upon himself, in which vomiting was induced with half a grain of cadmium sulphate. The chemical and toxicologic properties of cadmium he described as resembling those of zinc, and he was the first to suggest the toxicity of cadmium sulphide (yellow paint).

Marmé (2), in 1867, published the conclusions from his experiments with cadmium. He used dogs, cats, rabbits, and pigeons as experimental animals, and about fourteen (mostly soluble) cadmium compounds, giving them by intravenous and subcutaneous injections, by feeding, and by direct application on the skin. He concluded that cadmium salts which are soluble in water or in weak acids at body temperature are analogous in their poisonous action. He gives the lethal dose for dogs, by intravenous injection, as 30 mg.; for cats, 16 mg.; and for rabbits, from 10 to 20 mg. By subcutaneous injection, twice or three times this quantity was necessary to produce the same intensive action. Pigeons were killed by 15 mg. of cadmium chloride injected subcutaneously. Subcutaneous injections were followed by a severe local reaction, consisting in swelling, hyperemia, and pus formation. The lethal dose of cadmium, through the gastrointestinal tract, for rabbits (1,500 to

1,800 gm. in weight) was from 300 to 600 mg.; for dogs, cats, and pigeons it could not be established owing to the fact that cadmium taken into the stomach caused vomiting.

Toxic doses of cadmium, regardless of the manner of introduction into the organism, caused such reactions as vomiting, diarrhea, loss of energy, loss of appetite, and finally death. Small doses of soluble cadmium salts given over a longer period of time caused chronic intoxication, evidenced by gastro-enteritis and continuous loss of weight. On section, Marmé found occasional subpleural hemorrhages with infarction of the lungs, sometimes fatty liver and fatty heart, diffuse inflammation of the kidneys, inflammatory irritation of the stomach and intestinal mucosa with occasional hemorrhages and ulcerations. In concentrated solutions all soluble compounds had a caustic action. The excretion of cadmium he found to be slow and mainly through the urine. He declared cadmium sulphide absolutely safe for painting, basing his conclusions on experiments in which he noted no toxic symptoms in pigeons fed cadmium sulphide for one week. Certainly this is contrary to the facts as they exist today.

De Simone (10), in 1893, in his work on the action of cadmium on the nervous and vascular systems, injected dogs and frogs intravenously with from 1 to 3 gm. of cadmium in the form of cadmium glucosate, which is soluble in water, does not precipitate albumins, and has no local irritant action. He concluded that cadmium acts on the central nervous system, abolishing first the reflexes and then the sensation of pain, and resulting finally in death due to asphyxia, caused apparently by pulmonary edema with progressive respiratory paralysis and paralysis of the heart and vessels. None of the symptoms of asphyxia was preceded or accompanied by convulsions, thus indicating previous paralysis of the nerve centers. Cadmium reduced the blood pressure and paralyzed the vasomotor system, but had no action on the voluntary muscles or on the peripheral motor nervous system.

In 1895 and 1896, Athanasiu and Langlois (11) published a comparative study on cadmium and zinc salts. In the first part of their work they give the results of the action of cadmium sulphate and zinc sulphate on the lactic fermentation of colon bacilli. Cadmium sulphate in concentrations between 0.18 and 0.2 part per thousand completely inhibited fermentation; zinc sulphate was effective in concentrations between 1.5 and 1.6 parts per thousand. They observed the action of cadmium and zinc on the nervous system in frogs, and confirmed the fact that cadmium affects, first, the brain centers and, secondly, the circulatory system, causing a progressive decrease in cardiac rhythm. The pulse rate dropped from 45 to about 20 per minute. The systolic contraction became less energetic and there was a tendency toward longer diastole. The heart was usually not affected, since it reacted to mechanical or electrical excitation. The blood changes in dogs were intense hemolysis, formation of hematin, and increase in free seroglobulin.

Paderi (12), in 1896, repeated these experiments, using cadmium sulphate on frogs, birds, and mammals, and he

arrived at about the same conclusions concerning the nervous system as did the previous authors. He stated that cadmium is not a direct protoplasmic poison.

In the same year, Severi (4) published his findings on the lesions in the kidneys caused by cadmium chloride. He injected dogs and rabbits subcutaneously with 10 mg. of cadmium per kilo, employing a solution of 1 per cent. cadmium chloride in water. At the beginning the injections were made every day, then every other day. His animals died of doses about the same as those established by Marmé (2). At autopsy, the macroscopic appearance of the kidneys was very similar to that in mercuric chloride poisoning—greater in volume and pale. The microscopic findings also showed a great similarity to the lesions from mercuric chloride—intense necrosis in the convoluted tubules, many cellular elements poorly defined and pale, cells with irregular granulations, casts in some of the tubules, and frequent dilatation of the tubules. The casts appeared to be formed from the desquamated cells, and there were occasional calcified casts. The glomeruli showed no apparent alteration, and the collecting tubules were only very slightly involved.

Panseri (13), in 1904, studying the action of rubidium and cadmium on the heart of frogs and fish, found that cadmium was more toxic than rubidium, and that the salts of these two elements stopped the heart in diastole. Javillier and Tchernoroutzky (14), in 1913, observed that cadmium had an influence on the growth of certain Hyphomycetes similar to that of zinc, but was more toxic. Zinc in very small doses favored considerably the growth of Aspergillus niger. Kostychev and Zubkova (15), in 1916, noted that the reduction activity of yeast was very strongly inhibited by the cadmium ion. The proteolytic ferments, on the contrary, showed no change in their power in the presence or absence of cadmium. The following year Powers (16), in a monograph on the toxicity of different metallic salts, using goldfish as test animals, found that with ferric chloride, copper chloride, and cadmium chloride the toxicity increased with a decrease in concentration until a certain concentration was attained. With cadmium chloride the highest concentration used was 0.157 normal. The highest degree of toxicity was observed at 0.078 normal, from which point the toxicity progressively decreased with higher or lower concentrations.

In 1919, Alsberg and Schwartze (17) made some preliminary observations on the action of cadmium, and in 1923 they (18) published an extensive and conclusive piece of work on the pharmacology of cadmium and zinc with particular reference to emesis. They used cadmium chloride and have presented all their data in terms of metallic cadmium. Cadmium chloride in alcoholic solution rubbed on unbroken skin on the hairy portion of the forearm had no effect, and no cadmium was detected in the urine. Cats were used for the vomiting experiments and were fed cadmium and zinc in raw hashed, lean meat, in fish juice, and in meat extract. Since emesis occurred in proportion to the concentration of cadmium in the diet, and not in proportion to the absolute amounts taken into the stomach, the

data were recorded on this basis. Both cadmium and zinc were two or three times as effective in the liquid media as in the solid, and the authors' explanation is that the protein precipitation was relatively less in the liquid and that the mucous membrane of the mouth and stomach had a better opportunity to come in contact with the administered substance. Variations were observed in the reactions of the same animal, as well as in different animals. A retained cadmium meal usually lessened the sharpness of the appetite the next day. The time of vomiting also varied, but was usually within from one to four hours. In general, the emesis tended to occur sooner when the consumption of food was large or when the concentration of cadmium was high. Cadmium and zinc given by intravenous injection caused vomiting, as well as a considerable general toxic effect.

TABLE 1.—VOMITING EXPERIMENTS USING A MEDIUM OF RAW HASHED LEAN MEAT

CADMIUM IN FOOD	TOTAL EXPERIMENTS	EXPERIMENTS WITHOUT VOMITING	EXPERIMENTS WITH VOMITING	EMETIC EFFICIENCY
p.p.m.				%
100	6	6	0	0
150	41	31	10	24
200	33	16	17	51
250	37	17	20	54
300[1]	33	14	19	57
350[1]	5	1	4	80
400[1]	21	1	20[2]	96

[1] Arithmetic mean for 5 largest doses given, which were non-emetic, is 330 parts per million.

[2] Fifteen cats ate from 50 to 110 gm., and 5 others from 150 to 200 gm.

TABLE 2.—VOMITING EXPERIMENTS WITH LIQUID FOOD

CADMIUM IN LIQUID	TOTAL EXPERIMENTS	EXPERIMENTS WITHOUT VOMITING	EXPERIMENTS WITH VOMITING	EMETIC EFFICIENCY
p.p.m.				%
50	5	5	0	0
100	13	2[1]	11[2]	85
150	9	2	7[2]	78
200	3	1[2]	2	67
250	2	1[3]	1	50

[1] Two cats ate 15 c.c. each.

[2] One cat ate 15 c.c.

[3] Consumed 20 c.c.

It is of interest to reproduce in full some tables from the work of Schwartze and Alsberg. In Table 1, they present the results of vomiting experiments in which cadmium was fed through a medium of solid food, fifteen cats receiving from 20 to 44 mg. of cadmium, and five cats from 60 to 80 mg. The minimum emetic dose was 4.11 mg. per kilo, and the actual amount contained in the food was 150 parts per million of food. The maximum amount of cadmium tolerated without producing emesis was 22.7 mg. per kilo, and the actual concentration 400 parts per million of food. Table 2 gives the results of vomiting experiments in which cadmium was fed through liquid food. Here vomiting occurred sooner from smaller amounts of food and from lower concentrations of the metal than with solid food. The authors explain the failure of emesis in some of the experiments by the fact that small amounts of liquid pass more rapidly out of the stomach. It is also possible

that the large number of cases in which liquid food was rejected decreased the percentage of cases of emesis through elimination of many of the more sensitive cats. It may be noted that in the experiments with higher concentrations of cadmium (200 and 250 parts per million) very few cats were used, and the fact that the same cats were used again after resting periods of about one week should be taken into consideration. Subcutaneous injections were considered by the authors as wholly inadequate for accurate experiments, since they gave incomplete resorption and great local reaction.

In their experiments on the comparative toxicity of cadmium and zinc (Table 3), Schwartze and Alsberg gave smaller quantities than Marmé, and their results are more accurate and reliable since the amounts are expressed in metallic cadmium, while Marmé gives figures on the cadmium salts without indicating which salt was used for the particular result recorded. Zinc, calculated as a metal, was about equally toxic for all species (rats, rabbits, cats, and dogs). Cadmium was about three times as toxic as zinc for cats and dogs, and four or five times as toxic for rabbits and rats. Cats and dogs seemed to be more resistant to cadmium than rats and rabbits. These authors confirmed Powers' (16) observation that cadmium was more toxic in dilute solutions than in concentrated. They also observed that protein precipitation may occur in the vessels on intravenous injection. Final results are given for only eleven of the seventeen cats used for feeding experiments; the other six were discarded because of the impossibility of inaugurating regular feedings with quantities of cadmium

TABLE 3.—TOXICITY OF CADMIUM AND ZINC

ANIMALS USED	METAL USED	INTRAVENOUS ADMINISTRATION			SUBCUTANEOUS ADMINISTRATION			ORAL ADMINISTRATION		
		Usually Sublethal	Intermediate	Usually Lethal	Usually Sublethal	Intermediate	Usually Lethal	Usually Sublethal	Intermediate	Usually Lethal
		mg. per kilo			*mg. per kilo*			*mg. per kilo*		
Rats	Cd	1.0–1.5	2.0	3.0	10–25	40	100[1]	...	150[1]	...
	Zn	5.0–7.5	10.0	11.2–14.0	75–150	..	...	250[1]	...	500[1]
Rabbits	Cd	1.35	1.5–1.7	2.0	10–20[1]	25[1]	50[1]	50[2]	...	70[2]
								...	100[3]	150[3]
	Zn	...	6.5	10.0	50–100	..	...	250[2]	350[2]	435–500[3]
Cats	Cd	2.5	3.0–4.0	5.0[1]	10	20[1]	25–40	...	...	...
	Zn	6.5	10.0	...	..	100–115[1]	...	...	...	...
Dogs	Cd	3.0–4.0[1]	....	5.0[1]	..	..	...	...	...	...
	Zn	...	10.0[1]	15.0–25.0[1]	..	..	...	...	...	...

[1] Data probably insufficient.
[2] One-tenth and 0.2 per cent. solutions of cadmium used.
[3] One per cent. solution of cadmium used.

ranging from 500 to 1,000 parts per million (50 to 100 mg. per 100 gm. of food). One hundred gm. of meat were given daily for five days of the week, and 150 gm. on Saturdays, but the same absolute amount of cadmium. The experiments were carried on over a period of a year (sixty-four weeks was the maximum), and the quantities of cadmium offered in the food were from 50 to 500 parts per million (5 to 50 mg. per 100 gm. of meat).

On the whole, the animals on a diet containing 200 parts or less of cadmium per million of food maintained their own weight or increased in weight. Occasionally vomiting occurred or part of the food was uneaten. Cats receiving 250 parts or more per million usually vomited or left much of their food uneaten, and they lost weight. When the concentration was reduced to 200 parts or less per million, or when no cadmium was fed, recovery usually occurred. No symptoms which would indicate either a systemic cumulative effect or habituation to this metal were observed. There were two epidemics of distemper. One occurred in the winter, apparently because the laboratory was not well heated at night; in the other, which occurred in the summer, the cadmium was probably a predisposing factor. The symptoms were sneezing, coughing, and loss of appetite, and it was necessary to discontinue the cadmium diet in most of the animals until they recovered. In general the cats had little appetite for their food, and at times a single dose of cadmium, whether it produced vomiting or not, depressed the appetite for a day or two for meat containing no cadmium.

The chemical analyses of the viscera of these animals (Table 4) showed that the main storage of cadmium was in the liver and kidneys, the kidneys in general containing relatively much more than the liver. The progressive tendency for storing up cadmium when fed in larger doses over longer periods of time proves that cadmium is absorbed more rapidly than it is excreted. After periods on a cadmium free diet there seems to be a loss of the stored cadmium, and the fact that cadmium was found in the urine collected from the cages indicates elimination through the kidneys.

Johns, Finks, and Alsberg (19), in 1923, studying the influence of cadmium chloride on growth, noted that rats on a diet containing 250, 500, or 1,000 parts per million of cadmium showed very little or no growth, and that death soon occurred. With 125 parts per million the initial growth was normal, but the male rats died within fifty days, and while the majority of the females survived for a very much longer time, only two were alive at the end of 190 days, when one of them died. The other was still living at the end of 280 days, when the experiment was discontinued. A concentration of 62.5 parts per million of cadmium had no effect on growth, the rate of growth and food intake being normal. The food intake increased as the concentration of cadmium in the diet was decreased. Whether the interference with growth was due solely to diminished food intake was not determined. With a dosage of 0.56 mg. of cadmium per day no cumulative action was observed.

In the same year Hanzlik and Presho (20), in their work on the comparative toxicity of lead and other

heavy metals, fed metallic cadmium to pigeons. In two which were fed 1.22 and 2.23 gm. per kilo, respectively, for one week, no changes were observed. The third, which weighed 323 gm. and was fed 2.53 gm. per kilo for 156 days, showed a maximum loss of weight of 10.8 gm., appearing on the 117th day.

TABLE 4.—CADMIUM FOUND IN VISCERA OF CATS USED IN CONTINUED FEEDING EXPERIMENTS

CAT NO.	DURATION OF EXPERIMENT	CADMIUM OFFERED DAILY[1]	LIVER			KIDNEY			SPLEEN		
			Weight	Cadmium Found[2]		Weight	Cadmium Found[2]		Weight	Cadmium Found[2]	
	wks.	*mg.*	*gm.*	*mg.*	*%*	*gm.*	*mg.*	*%*	*gm.*	*mg.*	*%*
1	21	5	88.00	0.4	0.0005	11.5	3.8	0.0230	4.00	0.5	0.0012
2[3]	45	5	50.80	1.9	0.0037	17.8	1.3	0.0073	3.20	0.0	0
3	64	10–30	83.00	3.5	0.0042	27.5	2.9	0.0105	....	...	.....
4	64	15–30	80.00	11.2[4]	0.0140	....	...	.....	....	...	.....
5	64	20	102.00	1.8[4]	0.0018	31.0	4.0	0.0129	....	...	.....
7	6	30	29.20	1.6	0.0055	12.8	2.7	0.0211	4.20	0.9	0.0214
8	44	30	46.65	38.4	0.0823	16.0	9.3	0.0581	2.15	0.0	0
9[5]	21	35	125.00	4.0	0.0032	....	...	.....	6.50	0.0	0
10[6]	63	35	60.00	15.6	0.0260	20.5	6.4	0.0312	6.50	0.0	0
11[7]	11	50	81.50	1.4	0.0017	17.1	4.5	0.0263	2.00	0.0	0

[1] Offered but not necessarily consumed or retained.
[2] Mr. W. D. Collins, the analyst, states that several tenths of a milligram may be missed.
[3] Femur, stomach and intestines, muscle, lungs, and heart contained no cadmium.
[4] Part of sample lost in analysis.
[5] Brain, skin, and blood contained no cadmium.
[6] Brain and bone contained no cadmium.
[7] Blood, bile and gallbladder, muscle, femur, and large intestine wall contained no cadmium.

The experiments of Schwarz and Otto (21) were published two years later and may be reviewed as follows. The duration of experiments was two and one-half months, and the quantities were given in metallic cadmium.

Cadmium Sulphate

Four Rabbits.—Injected every other day subcutaneously with from 0.6 to 1 mg. of cadmium per kilo. Two rabbits died during the experiment. Autopsy showed general emaciation.

Four Rabbits.—Cadmium was introduced into the stomach through a catheter every day except Sunday in amounts of 0.16, 0.3, 0.6, and 1.2 mg. Two rabbits which lived until the end of the experiment showed at autopsy swelling and redness of the gastric mucosa.

Two Cats.—Cat 1 had 1 mg. of cadmium per kilo for two and one-half months, given in capsules every day except Sundays. Cat 2 was fed with increasing amounts of cadmium, from 0.8 to 2.4 mg. per kilo for four months. Autopsy showed nothing abnormal.

Cadmium Carbonate

(Given in capsules by mouth daily except Sundays.)

Cat 1.—4 mg. per kilo for two months. Autopsy showed general emaciation.

Cat 2.—5 mg. per kilo (ran away after four weeks).

Cat 3.—1 mg. per kilo. Died after six weeks. Autopsy showed redness and swelling of the gastric mucosa.

Cadmium Oxide

(Supposedly given by mouth.)

Cat 1.—2 mg. per kilo daily. Still under experiment.

Cat 2.—6 mg. per kilo. Died after two months and a quarter. Autopsy showed mucous secretion of the upper respiratory tract; stomach, nothing abnormal.

Cat 3.—11 mg. per kilo for two months. When the feedings were discontinued, the cat showed recovery. Still under observation.

The animals used in these experiments showed more or less pronounced loss of weight, sometimes followed by death. Some showed a decrease of from 10 to 20 per cent. in hemoglobin content (measured with the Sahli apparatus) shortly after the beginning of the experiment, a decrease in red cells, and an increase in leukocytes, especially the polymorphonuclears. In all cats except those fed with cadmium oxide, inflammation of the upper respiratory tract and of the conjunctivae was noted, sometimes within a few days and sometimes as long as two and a half months after the beginning of the experiment. These symptoms, however, were probably not directly due to the action of cadmium (22). Schwartze and Alsberg did not observe this condition in their large number of cats fed with cadmium. The only new contributions of Schwarz and Otto were the observations made in connection with the blood changes, and the warning given that cadmium in the form of fume or dust is a serious industrial health hazard wherever it occurs.

Otto (3), in the same year, published experiments on exposure to cadmium oxide in statu nascendi through the respiratory tract, the only attempt reported in the literature up to the present time to produce experimental cadmium poisoning through this system. For this purpose he constructed an apparatus (after Lehmann (23)) of about 100 liters' capacity, consisting of two glass bells; and for the production of cadmium oxide in statu nascendi he used a copper cell having one electrode of carbon and the other of cadmium. During the passage of the electric current the cadmium was transformed gradually into fine scattered particles, which were taken by the air, at a rate of 350 liters per hour (5.825 liters per minute), into the apparatus where the cats were exposed. Although Otto's experiments, with the exception of his observations of an increase in the hemoglobin content and the occurrence of pneumonia after exposure through the respiratory tract, did not result in any real contribution to the question, a résumé of his work is interesting.

Cat 1.—Exposed fifteen minutes in a concentration of 2 mg. of cadmium per liter of air. Increase in the rate of respiration was observed, also irritation of the conjunctivae and upper respiratory tract, salivation, and general depression. On the second and third days there were the same symptoms, and the respiration became stronger and noisy. Death followed on the fourth day. Increase was observed in the hemoglobin, red cells, and white cells, and relative increase in the polymorphonuclears. Autopsy showed double bronchopneumonia and pleural effusion.

Cat 2.—Exposed for only five minutes to about the same concentration, with the same symptoms and findings as were observed in Cat 1. It is not stated whether this cat died

or was killed. Autopsy showed bronchopneumonia and fatty degeneration of the liver.

Cat 3.—Exposed for five minutes daily, except Sunday, for ten successive days. The concentration of cadmium oxide was lower (figures not given). The same symptoms and blood changes were observed but without the relative increase in the polymorphonuclears. The cat died on the tenth day from pneumonia.

Cat 4.—Exposed daily for two and one-half minutes the same as Cat 3. On the sixteenth day of the experiment this cat showed no particular change except reduction in the hemoglobin content.

The year 1925 was rich in literature on cadmium. In addition to the articles already reported, there were two others, which mark the beginning of experiments in connection with the therapeutic use of cadmium compounds. Kochmann and Grouven (24) published a paper in which Kochmann presented the results of experiments on the pharmacologic action of cadmium, and Grouven reported clinical observations on the treatment of syphilis with cadmium compounds. Kochmann employed different inorganic and organic salts, but since all the compounds had the same qualitative effect he has described only his experiments with cadmium chloride as typical of them all. He observed that all cadmium compounds precipitate the albumins of the serum, medium concentrations having more intense precipitating action than higher or lower concentrations. Cadmium ion, when applied on living tissues, had an astringent action in medium concentrations, and an irritant, caustic action producing hyperemia in higher concentrations. Cadmium chloride in higher concentrations precipitated out the cholesterin from the lipoids. The red cells under the action of high concentrations agglutinated, and in the presence of weaker concentrations hemolysis occurred. Cadmium inhibited hemolysis in hypotonic salt solution and in saponin solution, and Kochmann believed that this might be due to the formation of a protective albumin coating on the surface of the red cells. Yeast fermentation was inhibited by cadmium compounds, and protozoa seemed to be very sensitive, being killed in a solution of 1:300,000 of cadmium chloride. Cadmium compounds were comparatively inactive for bacteria. The author gives an account of experiments on frogs, rabbits, and dogs, similar to those reported before, in which he found that the organic and the insoluble compounds were less active.

Up to this time cadmium had not been used in the treatment of syphilis. In 1924, Frost (25) merely suggested that cadmium might have an action similar to that of bismuth. Grouven was the first to apply cadmium in syphilis. He used cadmium salicylate in a 10 per cent. oily suspension with a cadmium content of about 5 per cent., and made intragluteal injections of from 0.5 to 1 c.c. twice a week. At the place of injection an infiltration appeared, similar to that which appears when mercury salts are used, and very painful. Transient albuminuria sometimes occurred. He tried the treatment on fifty-three cases in different stages and with different lesions of syphilis. He found that cadmium alone had absolutely no influence on the lesions, and he was about to give up further experimentation when he decided to combine cadmium and neosalvarsan. Although this treatment

did not cause the lesions to heal any more quickly, once they had disappeared it had a more pronounced effect on the Wassermann reaction than he had ever experienced before with any combined treatment of syphilis.

In the same year, also, Levaditi and his coworkers (26) published their experiments on the antisyphilitic properties of cadmium. They observed the effect of metallic cadmium, cadmium oxide, cadmium oxyhydrate, cadmium chloride, sodium cadmium tartrate, and chlorcadmiate of pyridine on rabbits with lesions of Spirochaeta cuniculi. In their control animals they used bismuth oxyhydrate. The majority of these compounds were used in an oily suspension (10 per cent.) injected intramuscularly. One animal was given cadmium chloride orally. A total of ten rabbits were used for this work. The lesions in the rabbits treated with cadmium salts did not show any change, but the animals lost weight and suffered digestive disturbances. The control animals, which had been treated with bismuth, showed improvement. These workers concluded therefore that cadmium had very little, if any, therapeutic action, and in any case was not better than bismuth and vanadium.

Lucke (27) also published observations on syphilis treated with cadmium. He combined neosalvarsan with cadmium and obtained good results. He analyzed the urine and feces, and found that most of the injected cadmium was excreted through the intestinal tract and that very small amounts appeared in the urine. A notice appeared in the *Deutsche Medizinische Wochenschrift*, in 1926 (vol. 52, p. 201), of the commercial preparation of the material used by Grouven and Lucke under the name cadmiol, already described as an oily suspension of 10 per cent. cadmium salicylate in liquid paraffin, the dose being from 0.5 to 1 c.c. twice a week intragluteally. The notice stated that the synergism of cadmium-salvarsan was better than mercury-salvarsan or bismuth-salvarsan.

In 1926, Reitler (28) published observations on the treatment of malaria with cadmium preparations. He used cadmiol for intramuscular injections, and preparation No. 716B, made by the same commercial house, for intravenous injections. Preparation No. 716B contained cadmium sodium tartrate, having about 1 per cent. cadmium. He treated three patients with this preparation, giving two of them two injections of 2.5 c.c. each, and the third only one injection. The schizonts disappeared from the blood very quickly, but the gametocytes remained somewhat longer. Immediately after the injections there appeared very serious secondary symptoms consisting of dyspnea, edema of the face, and mucous diarrhea. He then discontinued the treatment with intravenous injections and began administering cadmiol. The intramuscular injections were followed by a very painful local reaction, which was so severe that the patients refused the treatment. The greatest number of intramuscular injections was four, and only one patient received this number. Reitler observed quicker disappearance of the parasite from the blood in patients treated with cadmium than in those treated with

quinine. He recommended combined treatment with quinine and further experimentation.

Hessel (29), in the same year, reporting experiments on the therapeutic use of cadmium preparations, showed that cadmium injected intramuscularly or intravenously tended to be stored up and excreted very slowly. He made his observations on rabbits, dogs, and men. Three rabbits were injected intramuscularly with cadmiol and killed by bleeding at different time intervals. The urine and feces were collected for analysis, and after

TABLE 5.—RESORPTION OF CADMIUM FOLLOWING INTRAMUSCULAR INJECTION

RABBIT NO.	WEIGHT	TIME KILLED AFTER INJECTION	CADMIUM INJECTED	CADMIUM FOUND IN PLACE OF INJECTION	RESORBED
	gm.	*wks.*	*mg.*	*mg.*	%
1	1,370	1	30	14.5	51.7
2	1,360	2	30	15.4	48.7
3	2,185	8	20	3.7	81.5

death the different organs, as well as the tissue from the place of injection, were analyzed. The findings in this experiment, showing the very slow resorption of cadmium from the place of injection, are given in Table 5. After two weeks 50 per cent. of the injected quantity was unresorbed at the place of injection, and after eight weeks about 20 per cent. The animals showed a local reaction even a week after injection, and later cicatrization. Eight weeks after injection 4 mg. of cadmium were found in the liver of Rabbit 3, 2.6 mg. in the kidneys, and 0.3 mg. in half of the intestinal tract, which, together with the amount found in the place of injection, totaled 53 per cent. of the cadmium injected. From Rabbit 2 he recovered about 70 per cent. of the injected cadmium; he does not give the results of the analysis of the viscera of Rabbit 1. In a dog injected intravenously with 20 mg. in a soluble salt of cadmium and killed after four weeks by bleeding, 38 per cent. of the injected cadmium was found in the organs. The largest quantities were found in the liver and kidneys, as was shown by Schwartze and Alsberg; this is also in accord with the author's (22) findings.

TABLE 6.—EXCRETION OF CADMIUM BY PATIENT TREATED WITH CADMIOL

DATE	CADMIUM INJECTED UP TO DATE	CADMIUM FOUND IN	
		Urine	Feces
	mg.	*mg.*	*mg.*
Feb. 20–22	400	0.50	1.50
23–25	450	0.30	0.60
26–28	500	0.60	1.00
March 1–3	550	0.70	1.90
4–6	600	traces	1.00
7–9	650	0.40	0.70
10–12	700	0.20	none
13–15	700	traces	0.25
16–18	750	0.80	0.90
19–21	750	0.30	0.75
22–24	800	0.15	1.60
25–27	850	0.40	1.35
28–30	900	0.38	traces
31–Apr. 23	950–1,200	not analyzed	
Apr. 24–26	1,250	0.25	0.85

To illustrate the extremely slow excretion of cadmium, Hessel's observations on a person treated for

syphilis with cadmium are given (Table 6). The urine and feces were collected and analyzed. During a period of thirty-nine days about 5 mg. of cadmium were excreted in the urine and about 11.5 mg. in the feces, making a total of 16.5 mg., which represented only 3 per cent. of the quantity injected. Certainly a large portion of the 900 mg. must have remained in the place of injection, while still more must have been stored up in the liver and kidneys, and, as found in the author's (22) investigations, in the bones also.

In the urine and feces collected from the dog injected intravenously, he found the cadmium excretion in the same minute amounts as in his syphilitic patient but with the difference that more was excreted in the urine than through the intestinal tract. He could not detect cadmium in the blood of one dog which was killed by bleeding four hours after the injection, nor did he detect cadmium when analyzing four ribs from Rabbit 3.

These experiments, therefore, explain why cadmiol is not effective in the treatment of either syphilis or malaria, and it is the opinion of the author (22) that the cadmium stored up in the liver and kidneys during such treatment may seriously damage these organs.

In 1926, Cooper and Robinson (30) also published an article containing observations on the bactericidal action of cadmium compounds. They arrived at the conclusion that cadmium compounds were more efficient germicides than the salts of many other metals, with the exception of silver and mercury, the organic compounds tending to be less effective than the inorganic.

At this time a turning point in the therapeutic use of cadmium was reached. Walbum, following a very extensive study of the influence of different metallic salts on biologic reactions and biologic products, and particularly on the production of staphylolysine (31), where cadmium among other metallic salts had a favorable action, performed some animal experiments to determine the influence of various metallic salts on the formation of agglutinins and amboceptors, or sensitizers, and also to determine their influence on acute infections and on tuberculosis (32). He observed that these metallic salts should be applied in an optimum concentration, because too high concentrations caused poisoning and inhibited the formation of antibodies, thus producing a condition favorable to infection. At the same time Schmidt (33), working on the formation of antibodies in horses immunized against diphtheria, observed that among other metallic salts cadmium had a stimulating action on the formation of antibodies. He noticed that of all the metallic salts used (calcium, barium, strontium, beryllium, magnesium, zinc, and cadmium) cadmium was the most toxic, developing heavy sweating which lasted from one to two hours, and a rise in temperature to 38°C.

In 1926, Walbum (34) published a series of experiments on the treatment of tuberculous guinea-pigs with cadmium and other metallic salts. He started the treatment on the twenty-third and thirty-third days after the animals were infected with tubercu-

losis, and in both series the cadmium had a very favorable action. All the animals treated in the same way with other salts, however, and also the control animals, showed tuberculosis at death.

These favorable conclusions on the treatment of tuberculous animals with cadmium led to its clinical application, and Lunde (35), in 1926, published an article on the treatment of tuberculosis by Walbum's method. He observed fifty-two cases and obtained a negative sputum in 63 per cent., which at the beginning of the treatment were positive for Koch bacilli. In 92 per cent. of the cases there was an average increase in weight of 6.4 kg. During the treatment peritoneal, pleural, pleuropulmonary, and glandular reactions were noted. Lunde explained that cadmium had a primary nonspecific action, evidenced by decrease in temperature, which destroys the toxins; and a specific action, manifested by increased bacteriolysis and chemotaxis with liberation of endotoxins. He warned against the use of large or rapidly increasing doses, emphasizing the danger of fatal toxicosis resulting from rapid destruction of toxins. It is now known that this fatal toxicosis is not due to the destruction of toxins but is the toxic effect of the cadmium.

Reiter (36), in 1927, published observations on the treatment of dementia praecox with cesium and cadmium, using Walbum's method. He noted fewer relapses, especially complete relapses, among those treated with cadmium.

Lyding (37), in 1929, endeavoring to repeat Walbum's experiments on the therapeutic influence of metallic salts on infectious diseases, obtained just the opposite results. The following year he (38) published another series of experiments, from which he concluded that cadmium chloride had no effect on bacterial infection. Ziegler and Dörle (39) used three cadmium compounds in their work on the resistance acquired by bacteria against metallic salts, observing a gradual increase in the resistance of the bacteria toward the disinfectants. In an article on bacterial chemotherapy and the medium used, they (40) concluded that the bactericidal action of different metallic salts was greatly reduced by adding various colloid solutions such as animal coal, iron hydroxide, kaolin, serum, blood, and gelatin.

Summary and Conclusions

A review of the literature on cadmium poisoning shows that up to the present time most of the work has had to do with the physiologic and pharmacologic action of the metal. The pathologic changes reported, with the exception of the changes in the kidneys, are only suppositions with no confirmatory evidence. Many valuable data on feeding experiments are given, but only one experiment on exposure through the respiratory system was found, and this was very incomplete. From the standpoint of industrial hygiene, the experiments on the respiratory system are of capital importance because of the greater possibilities of exposure through this system and the far more damaging consequences.

From the published observations on experimental cadmium poisoning

the following conclusions may be drawn:

1. Cadmium in relatively small doses is lethal for different experimental animals (dogs, cats, rabbits, frogs, etc.).

2. Cadmium has a direct paralyzing action on the central nervous system and also on the vasomotor system.

3. Cadmium induces vomiting when given orally and also when introduced into the general circulation, and produces a general toxic effect.

4. When introduced into the organism (whether orally or by injections) cadmium has a tendency to be stored up, mainly in the liver and the kidneys.

5. The elimination of cadmium from the organism is very slow and is effected through the kidneys and the gastro-intestinal tract. At autopsy, animals fed or injected with cadmium show a fatty condition of the liver and nephritis.

6. Cadmium taken through the respiratory system gives a generalized pneumonia and sometimes pleural effusion.

7. The feeding experiments show a decrease in the hemoglobin content of the blood, and exposure through the respiratory system an increase. In both cases a relative increase in the polymorphonuclear leukocytes takes place.

8. Cadmium has no practical importance as a therapeutic and bactericidal agent.

Cadmium Poisoning in Man

The first known cases of cadmium poisoning were reported by Sovet (1), in 1858, in three servants who were polishing silverware with cadmium carbonate. The powder, dipped in juniper and put on the vessels in a thin layer, was brushed off when dry. One servant did this work for an entire day, and at the end of the day felt a dryness in his throat and a sensation of tightness in his chest. The next day he was aided by two other servants, all three working in the same room. In brushing off the powder they produced a considerable cloud of dust in the room, and by 1 o'clock in the afternoon, after they had eaten their lunch, they all showed symptoms of dizziness, difficult respiration, vomiting, and diarrhea. The two servants who had worked for only half a day gradually had an amelioration of the symptoms, but the third grew steadily worse and nearly died during the following night. He presented the following symptoms: extreme pallor, cold extremities, great prostration, low pulse, cramps in the legs, headache, sensation of constriction in the throat, chest, and epigastrium, continuous nausea, very frequent vomiting, hiccoughing, incessant colic, diarrhea and bloody stools, and tenesmus of the bladder with very little urination. The next day he showed a little improvement, although his face became congested. On the third day the nausea and vomiting ceased but a dysentery form of diarrhea continued. On the eighth day he became convalescent. The other two servants had similar symptoms but in a much milder form. Chemical analysis of the powder showed that it was cadmium carbonate. Sovet does not emphasize the respiratory symptoms particularly, but from other case reports, and also from the author's (22) animal experiments,

it is certain that at least the servant exposed for a day and a half had pneumonia.

Wheeler (41), in 1876, reported two cases of poisoning from cadmium bromide, which was taken orally instead of ammonium bromide, having been wrongly labeled at the factory. In these cases the symptoms were extremely pungent taste, very severe vomiting, complaint of pain and burning sensation in the stomach, and diarrhea. The vomiting and diarrhea lasted fully five hours, and during part of the time the pulse was imperceptible. The quantity taken could not be estimated.

Stephens (42), in 1920, reported the history of a man 67 years old, who had worked for many years in spelter works (zinc smelting), and who had received compensation during a period of ten years for "plumbism." The chief symptoms were weakness, loss of weight, and a tendency to bronchitis. At autopsy chronic interstitial nephritis was found, and also hypertrophied heart. The chemical analysis of the liver showed no lead, but traces of copper, 0.91 grain of cadmium per pound, and 0.77 grain of zinc per pound (1 grain = 64.797 mg.). These findings convinced him that the case was not lead poisoning, but cadmium and zinc poisoning. He stated that during a period of six years he had eight similar cases among spelter workers, where the analysis of the liver showed cadmium in quantities varying from 0.094 to 0.91 grain per pound of liver and zinc from 0.03 to 0.77 grain per pound, while the amount of lead was, if any, merely a trace. He said that spelter workers very often have symptoms which might be attributed to cadmium, such as pain or tenderness at the epigastrium, associated with nausea and some constipation, sometimes diarrhea, loss of appetite, thirst, an unpleasant taste in the mouth, and a thickly furred tongue.

Tracinski (43, p. 82), in 1888, called attention to the possibility of cadmium poisoning in zinc foundries. Since the Silesian blue powder from calamine contained 5 per cent. of cadmium, he was inclined to attribute the digestive disturbances leading to early cachexia among the zinc foundry workers to cadmium.

Sigel (44), in 1906, in his work on zinc fume fever, admits the possibility of the noxious effect of cadmium vapors in zinc smelting.

In 1921, Teleky and Brezina's (45) international review of industrial diseases for the years 1914 to 1918 appeared, and in it they mentioned an interesting case of poisoning which occurred in 1914 in the nickel-cadmium section of a factory manufacturing mine safety lamps. Cadmium plates were made for the lamps by means of a pressing machine. One of the men employed at the machine became ill, having symptoms of weakness, loss of appetite, and vomiting, which lasted for three weeks. The physician in charge suggested the possibility of poisoning by inhalation of the cadmium oxide dust used in the manufacturing process, and also the possibility of ingestion from eating lunch with dirty hands.

Legge (46), in 1923, reported three cases of cadmium poisoning occurring in a paint factory and resulting in the death of the engineer in charge of the factory. Usually the factory had

received its metallic cadmium in the form of sticks, but a few months previously it had received some of the metal in the form of ingots, which had to be melted down to reduce their size. The operation of melting was carried out by the engineer, assisted by two men, in a gas heated circular crucible, the work being done in an inadequately ventilated room. The operation lasted three hours. All three of the men became seriously ill, and the engineer died. The symptoms were dryness of the throat, headache, rapid pulse, nausea, passage of brown-colored urine, and sensation of cold. Autopsy on the engineer revealed congestion of the larynx, trachea, and bronchi, as well as of the stomach and intestines; fatty condition of the heart and liver; hemorrhagic inflammation of the spleen; and acute inflammation of the kidneys. The chemical analysis showed no trace of cadmium, but Legge did not state what organs were analyzed. Measurements of cadmium particles taken 4 feet above the crucible showed that 96 per cent. were under 2 microns.

Schwarz (5) reported a case of cadmium poisoning in a man employed in December, 1928, to melt cadmium in a metal foundry. At about 11 o'clock thick fumes were evolved in the room, which was without ventilation, and in the afternoon the patient developed vehement coughing and headache. On his way home he fell asleep in the street car, and fainted on the walk to his house. He went to bed immediately on arriving home, and during the night had such a vehement attack of coughing that he was obliged to call in a doctor, who found inflammation of the lungs, and inflammation and dilatation of the heart, and advised him to go to a hospital. On the next day he had nausea, shivering, pains in the sternal region, difficulty in respiration, and incessant coughing. The diagnosis at the hospital was bronchitis and bronchopneumonia. The lung healed quickly and the bronchitis showed progressive improvement. When the man was discharged from the hospital he still had numerous dry sibilant râles on both sides of the lungs. In April, 1929, he was found doing light work on a wharf. In December, 1929, he complained of salivation, shortness of breath while working, and swelling of the left foot by evening. The findings were: capacity of the lungs, 3,900 c.c.; retention of respiration, 57 seconds; at auscultation and percussion, nothing abnormal; irregular heart beating; and edema of the legs. Schwarz supposed that the reduction in the capacity of the lungs and the short retention in breathing was due to cadmium poisoning. The heart trouble dated back to a previous illness in 1927. He concluded by saying that at that time it was impossible to know the consequences of the lung inflammation caused by cadmium poisoning.

Physical and Chemical Properties of Cadmium

Cadmium (Cd) belongs to the second group of Mendeléeff's system, being in the subgroup with zinc first, cadmium second, and mercury third. It is a white metal possessing a bluish tinge, with a bright luster, capable of taking high polish. On paper it produces a metallic streak but less readily than lead. When broken it shows a distinct fibrous fracture. It is harder than tin but softer than zinc, and like tin emits a crackling sound

when bent. It is malleable and can be rolled out in sheets or drawn out in thin wire. It has an atomic weight of 112.41; specific gravity of 8.625 at 20°C.; melting point at 321.6°C.; and boiling point 778.9°C. at a pressure of 760 mm. It is insoluble in water and soluble in acids. It gives off a yellowish-brown fume, and by distillation in a current of hydrogen may produce regular octahedral crystals and other forms of the cubic system. When heated in air it burns readily, evolving a brown fume of cadmium oxide. The most important compounds of cadmium are the oxide, sulphate, sulphide, chloride, iodide, and bromide.

Cadmium oxide (CdO) is a brown powder with a specific gravity of 6.5, insoluble in water and soluble in acids. It is obtained by burning metallic cadmium in the air or in oxygen, etc.

Cadmium sulphate ($CdSO_4 4H_2O$) is a very soluble salt, prepared by dissolving cadmium oxide or carbonate in sulphuric acid.

Cadmium sulphide (CdS), called also cadmium yellow and jaune brilliant, is a pigment which may be produced by the addition of hydrogen sulphide or an alkaline sulphide to a solution of a cadmium salt. It is orange yellow or lemon yellow in color, and its specific gravity is 4.8. It is slightly soluble in water (0.00013 gm. per liter), and in hot water forms a colloidal solution; is very soluble in ammonium hydroxide; and is soluble in acids.

Cadmium chloride ($CdCl_2$) is obtained by evaporating a solution of the metal or oxide in hydrochloric acid.

Cadmium iodide (CdI_2) is obtained by digesting 1 part of the metal with 2 parts of iodine in water, and evaporating the water; it crystallizes in large transparent tablets which are soluble in water and alcohol.

Cadmium bromide ($CdBr_2$) is obtainable in much the same manner as the iodide, giving prismatic crystals soluble in water.

Occurrence of Cadmium

Cadmium does not occur naturally in an uncombined condition, and only one mineral is known which contains it in any considerable quantity, namely, greenockite or cadmium sulphide, found in Greenock and Bishopton in Scotland, in Bohemia, and in Pennsylvania, Missouri, Arkansas, and Colorado in the United States. It is, however, nearly always found associated with zinc ores, in relatively small quantities, and is obtained as a by-product in the distillation of zinc. Greenockite (cadmium sulphide) contains 77 per cent. of cadmium and is honey colored, citron yellow to orange yellow. In the zinc ores, cadmium is found with zinc sulphide (blende), zinc carbonate, and zinc silicate as cadmium sulphide and cadmium carbonate. The name calamine is sometimes used for zinc carbonate and also for zinc silicate. The cadmium content of zinc ores varies generally from 0.1 to 0.5 per cent. Occasionally zinc ores are found which contain from 2 to 5 per cent. of cadmium. According to Clarke (quoted in (7)) zinc is 200 times as abundant as cadmium.

Extraction of Cadmium

Cadmium is extracted from zinc ores and zinciferous residues and by-products by two methods, dry and wet. With the dry method the procedure is in general as follows:

received its metallic cadmium in the form of sticks, but a few months previously it had received some of the metal in the form of ingots, which had to be melted down to reduce their size. The operation of melting was carried out by the engineer, assisted by two men, in a gas heated circular crucible, the work being done in an inadequately ventilated room. The operation lasted three hours. All three of the men became seriously ill, and the engineer died. The symptoms were dryness of the throat, headache, rapid pulse, nausea, passage of brown-colored urine, and sensation of cold. Autopsy on the engineer revealed congestion of the larynx, trachea, and bronchi, as well as of the stomach and intestines; fatty condition of the heart and liver; hemorrhagic inflammation of the spleen; and acute inflammation of the kidneys. The chemical analysis showed no trace of cadmium, but Legge did not state what organs were analyzed. Measurements of cadmium particles taken 4 feet above the crucible showed that 96 per cent. were under 2 microns.

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Extraction of Cadmium

Cadmium is extracted from zinc ores and zinciferous residues and by-products by two methods, dry and wet. With the dry method the procedure is in general as follows:

The zinciferous material, in an oxidized condition, generally as a consequence of roasting in the air, is mixed with an equal volume of coal and charged into a number of small clay or carborundum retorts capable of holding from 35 to 100 pounds of recoverable metal. These retorts are permanently set into a firing chamber or massive and heated by natural or producer gas to a temperature of from 1,200° to 1,400°C. At this temperature the metal oxides are reduced to the metallic state and are swept out of the retorts by their vapor pressure along with the carbon monoxide resulting from the reducing reaction. Luted to the front ends of the retorts or muffles are small, truncated cone, clay vessels which project outside the heated zone of the furnace and serve as condensers for the metal. Attached to the end of the condenser and projecting still further away from the hot zone there is a metal canister or blue powder condenser commonly known as a prolong. This metal canister condenses and settles out the more volatile elements vaporized from the zinciferous charge, as well as that part of the zinc vapor which has not condensed to liquid metal in the zinc condenser proper. The powdery material caught in the metal canister, or prolong, as a by-product from the normal working of zinciferous materials for the recovery of metallic zinc is called blue powder and contains from 1.5 to 4 per cent. of cadmium, the remainder being largely zinc with small amounts of other volatile elements such as arsenic and lead.

Not all of the cadmium finds its way to the metallic prolong and is caught in it. Some is condensed and dissolved in the liquid zinc in the condenser and some of it escapes along with the noncondensable gases which pass through both condenser and prolong and burn at the exit from the prolong. This blue powder from zinciferous material high in cadmium serves as a raw material for cadmium production. When the cadmium is to be recovered by the dry process, the blue powder is recharged with coal or coke in another set of retorts, which are operated at a lower temperature—about 800°C.—and the cadmium recovered by repeated fractional distillation. This process is based on the fact that the cadmium volatilizes at a considerably lower temperature than the zinc. Blue powder may also be dissolved directly in sulphuric acid and the cadmium recovered by the wet process described later.

Most of the cadmium recovered in the United States is a by-product in the manufacture of purified zinc sulphate solutions from zinc ores or zinciferous materials. These purified zinc sulphate solutions are used for the manufacture of zinc by the electrolytic process or for the manufacture of lithopone which results from the addition of barium sulphide to a solution of zinc sulphate. In this process of producing very pure zinc sulphate solutions, the oxidized ore or zinciferous material is first dissolved in sulphuric acid and then treated with metallic zinc in the form of slabs, sheets, atomized zinc, or blue powder. The zinc displaces the cadmium in solution, which is deposited in the sludge as metallic cadmium along with lead and the other heavy metals. This sludge is known as heavy metal residues.

Following out an entirely wet process, these residues are dissolved in sulphuric acid, which leaves copper behind. Cadmium, cobalt, and nickel dissolve. The cadmium is electrically precipitated from this solution by maintaining the proper voltage and current density on the cathodes. The cathode cadmium is made by hand into briquettes roughly 6 inches by 8 inches, melted under oil, and cast into sticks or slabs. Sometimes these residues are purified by re-solution in concentrated sulphuric acid and reprecipitation by zinc until there is a precipitate containing about 60 per cent. of cadmium with lead, zinc, etc. These residues are stored away to dry in piles, sometimes covered and sometimes uncovered, from one to eight months. The dry residue is distilled in the blue powder furnace, with iron retorts, and the cadmium vapors are condensed and cast into finger molds. The metal cast is classified according to its purity, and is then melted in a graphite crucible and cast into sticks or small slabs. The residues from the retorts containing about 1 per cent. of cadmium are stored and reworked. In general, the blue powder resulting from the manufacture of zinc is collected and used for the manufacture of cadmium, which is carried on for about two months in the year.

The manufacture of cadmium oxide is similar to that of metallic cadmium up to the point of distillation, when the cadmium vapors are burned instead of condensed and the oxide formed is collected in bags attached to the discharge end of the ventilating system of the blue powder furnaces.

Cadmium sulphide is manufactured in two shades, the bright citron yellow which is made by precipitation of cadmium with hydrogen sulphide from a slightly acid solution, and the orange yellow which is precipitated from a strong acid solution.

Uses of Cadmium

Cadmium is used very little as a metal. It is used, however, as a constituent in many alloys with low melting point for the preparation of amalgams and for the preparation of its salts. To simplify matters, the word cadmium will be used here as a general term for any of the compounds except when otherwise specified. The extensive industrial use of cadmium was developed after the war, and especially after its application in electroplating. In the past century cadmium was occasionally used for alloys with low melting point, and the forms most extensively used were cadmium iodide and cadmium bromide in photography, as quoted by Dragendorff (47), in 1876, and by Hager (48), in 1880. For many years most of the cadmium was produced in Silesia. In the United States (49) the production began in 1906, when the Grasselli Chemical Company extracted cadmium from blue powder, and steadily increased so that after the war the United States took first place in the world production, the second place being held by Germany. The alloys of cadmium are mostly binary, tertiary, and quaternary. The presence of cadmium, sometimes in surprisingly small amounts, gives qualities of great practical value to the alloy. The observation that cadmium made a good rust preventive coating was followed by

the development of cadmium plating, which in several respects surpasses nickel and other protective metals used in this manner.

In 1920, the Udylite Process Company of Kokomo, Ind., developed a commercial process, and new installations were taking place at the rate of from six to eight per month. In 1923, a cadmium plating process was patented in Canada by Wissler and Humphries (50). Several methods differing very little from one another were patented in the United States in 1925, developed by Louth and Young (51), Humphries (52), and Young (53). Young (54) also obtained coloration of cadmium coated articles by treating them with an ammoniacal solution of ammonium molybdate at temperatures varying between 38° and 82°C. in an electric circuit in which the article served as the cathode. Cadmium plating was introduced in Europe in 1926. In 1927, a German firm applied for permission to use cadmium in plating such household articles as spoons, knives, and forks, but its petition was refused on the basis of the unfavorable reports resulting from investigations made by Gronover and Wohnlich (55), who observed that cadmium was dissolved from cadmium plated articles which came in contact with solutions containing from 0.5 to 2.5 per cent. of acetic acid and with plum marmalade. Dubpernell (56), in 1929, also advised against the use of cadmium plated articles, especially those coming in contact with acid foods.

Cadmium coatings are applied by electroplating and consist, in general, of cadmium carbonate dissolved in a solution of sodium cyanide, and some substance, usually protein (milk, cheese, casein, wool shellac, glucose, licorice, etc.), which favors a more uniform deposition of cadmium on the articles. The cadmium content of the solution varies from 0.2 to 4.3 per cent., and the sodium cyanide content from 0.2 to 7.1 per cent. The cadmium coating may be applied also by a spraying process, but the high cost of the cadmium wire necessary for carrying out this process has not encouraged the development of this method.

Coincident with the development in plating, there was an increase in the uses of cadmium in other fields. Budgen (57), in 1928, reported the application of cadmium in the manufacture of alkaline storage batteries, standard cells (as mercury-cadmium alloy), high temperature resistors, and cadmium vapor lamps; he predicted an important future in the application of cadmium to copper. There was also a development in the application of cadmium base pigments called lithopones. Zinc lithopone is composed of zinc sulphide and barium sulphate; cadmium lithopone is composed of cadmium sulphide and barium sulphate. The cadmium lithopones are obtained, according to Hutin (58), by precipitating cadmium sulphate with barium sulphide. The cadmium yellows mixed with ultramarine blues give brilliant and very stable greens.

Health Hazards Associated with Cadmium

The greatest health hazards are found in the manufacture of cadmium and in the handling of the compounds. The following list shows

where the most hazardous exposures have been encountered:

1. Vapor or fume from the retorts or condensers of the blue powder furnaces, in making both cadmium and cadmium oxide.
2. Fume from and near the collecting bags in making cadmium oxide. The particles which constitute this fume are so small that a large percentage of them are not caught in the bags.
3. Dust in handling cadmium oxide, as such, especially in emptying the bags and packing.
4. Fume from working up the blue powder furnace residues at the furnace and in the bag room.
5. Shaking the bags in the bag room (blue powder) of the zinc smelting kiln.
6. Emptying the blue powder from the bags of the zinc smelting kiln, storing it, and transferring it to the blue powder furnace or for the wet treatment.
7. Working up the blue powder by the wet method—that is, in handling the blue powder and the solutions with high concentrations of cadmium.
8. Handling the metal residues stored for drying.
9. Manufacturing and handling lithopone and working up the residues from this process.
10. Manufacturing and handling cadmium sulphide.
11. Spraying cadmium sulphide (as a paint).
12. Welding alloys containing cadmium or cadmium coated articles.
13. Melting metallic cadmium or its compounds without adequate ventilation.
14. Handling any cadmium compounds which may be inhaled or ingested.
15. Using cadmium coated or plated articles for any purpose where they may come in contact with food or drink.

It may be mentioned here that the oxide is sometimes used as a source of cadmium in cadmium lithopone manufacturing, in cadmium plating, and in the manufacture of cadmium sulphide. It is not yet known how great a health hazard there may be in the process of cadmium plating after the cadmium is in solution. The only observation which has been made up to this time is that the solution coming in contact with the skin causes it to turn black.

The presence of arsine in the manufacture of cadmium constitutes a further health hazard; and the fire hazard in connection with the blue powder and the cadmium sulphide should also be noted.

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BOOK REVIEWS

OCCUPATIONAL DISEASE LEGISLATION. Report of Committee on Standard Practices in the Problem of Compensation of Occupational Diseases of the Industrial Hygiene Section, American Public Health Association. Issued by the Committee on Research and Standards, American Public Health Association. Paper. Pp. vii, 124 with index. New York: American Public Health Association, 1931.

The purpose of this publication is well presented by the committee in its statement, "This compilation of occupational disease legislation, it is hoped, will serve those agencies both legislative and social, employers, insurance companies, as well as labor organizations who are interested in improving or changing existing legislation (workmen's compensation laws) to conform with modern progress and standards."

The committee believes that occupational diseases should be compensated for on the same basis as other industrial injuries. The arbitration of claims arising under occupational disease legislation is a more difficult task than the usual run of industrial accidents as "the conditions resulting from diseases do not lend themselves so readily to interpretation and indemnification as accidental injuries and their end results."

Chapter I of the report deals with the development of workmen's compensation laws as a problem of social economics. It is noted that the two earliest laws covering employer's liability for industrial accidents—Switzerland in 1877 and Germany in 1883—included payments for industrial diseases. The later laws, especially in the United States, "fell upon evil days," and much of the legislation compensated the injured worker only for personal injuries "by accident." The committee offers as a probable explanation for the exclusion of occupational diseases from coverage under many of the laws the fact that "by the time disability (from disease) is established, the diagnosis of its chain of causation may be obscured, and the workman affected may have changed occupation or employer several times over."

A résumé of the laws of foreign countries and of the various states is included in the report. A rough classification of the compensation acts at present in effect is:

1. Laws which definitely include occupational diseases:
   a. Those having a schedule naming the diseases compensable.
   b. Those having a schedule of diseases but limited to workers engaged in listed industrial operations.
   c. Those having no schedule of diseases or processes.
2. Laws which do not specify occupational diseases, but where the wording allows the industrial commissions or boards to find the disease to be a "personal injury" incidental to the employment.
3. Laws which exclude occupational diseases except those which result from "accidents."

It was found that the length of disability due to occupational diseases is generally longer than that due to accidental injuries, and an estimate is

made that the cost of compensating occupational diseases does not exceed 2 per cent. of the employer's cost for accidental injuries.

The confusion existing in regard to claims for compensation for diseases, both occupational and otherwise, as well as the lack of any definite standards for the diagnosis of diseases due to industrial exposure, and for the determination of the employee's economic disability, suggests to the committee the desirability of providing medical advisory boards to assist the various compensation commissions. It is felt that the advice of such boards might also have a constructive effect in the drafting of regulations for the prevention and control of hazardous industrial conditions.—*Charles F. Horan.*

SCHOOL VENTILATION. PRINCIPLES AND PRACTICES. Final Contribution of the New York Commission on Ventilation whose work was financed by the Milbank Memorial Fund, 1913–1923, 1926–1929. Cloth. Pp. 73 with bibliography. New York: Bureau of Publications, Teachers College, Columbia University, 1931.

This is a brief final report summarizing the eighteen years' study of the New York Commission on Ventilation on the problem of air conditioning for schoolrooms.

After reviewing the history and objectives of ventilation in the light of laboratory researches by the Commission and others, the authors describe the earlier (1913 to 1917) and the latest (1926 to 1929) field studies of the Commission in various urban and rural schools. The discussion is excellent and straightforward, and the book itself is a marked contrast to earlier publications.

Briefly, the problem of schoolroom ventilation was found to consist in maintaining the classrooms at a temperature between 68° and 70°, and in providing a sufficient air change to avoid unpleasant body odors without at the same time producing chilling drafts. According to the Commission, these conditions can be met by the use of at least three methods, depending on local conditions, when proper design and operation is provided: (*a*) by central plenum ventilation; (*b*) by local unit ventilation systems; and (*c*) by window-gravity ventilation. It is contended that the usual air change of 30 cubic feet per minute per pupil required by law in many states is unnecessary and highly wasteful. Data are presented to show that reducing the air supply from 30 to about 15 cubic feet per minute per pupil results in no appreciable difference in the incidence of respiratory illness among pupils. This reduced air supply can be secured by the use of window-gravity ventilation methods, while an air change of 30 cubic feet per minute per pupil can be accomplished only by mechanical methods.

On the strength of these data and in the interest of economy, the authors resume with renewed strength the resolution adopted by the American Public Health Association in 1925, seeking for a change or repeal of laws which interfere with the use of window-gravity methods by calling for an air supply of 30 cubic feet per minute per person. Suggestions are given for a model ventilation code which lays down the essential features as outlined by the Commission, and permits the use of any system capable of meeting these objectives.

The code has several commendable features, namely, flexibility, simplicity, and brevity; but in the reviewer's opinion, it fails to give due credit to local factors such as air cleanliness, humidity, and distribution, which the Commission does not apparently consider pertinent to the problem of schoolroom ventilation.

While it is true that the legal air supply of 30 cubic feet per minute per person is not justified by any physiologic or biologic evidence, it is equally true that owing largely to imperfections in present distribution methods, such a large volume of air is often necessary in order to secure proper distribution, freedom from odors and chilling drafts, and equalization of temperature in different parts of the room. As a matter of fact, where the law permits partial recirculation, plenum systems are designed on the basis of 30 cubic feet per minute per person with provision, in the interest of economy, for recirculating 50 per cent. or more of the air supplied to classrooms. In such instances, the quantity of outdoor air heated to room temperature is substantially the same as that in the Commission's window-gravity system. But if 15 cubic feet per minute per pupil will fulfil the requirements, as the Commission contends, it seems unnecessary to install plenum systems. Herein lies the gist of the controversy at present. No matter how imperfect the Commission's findings may be, it would be necessary for the ventilating engineers to produce satisfactory evidence in order to uphold their side of the controversy; namely, that 30 cubic feet of air per person per minute is the minimum requirement for adequate ventilation.

The unbiased critic would probably be in sympathy with the Commission's resolution to modify existing laws so as to fix the requirements rather than the methods for securing them. It must be admitted, however, that in the light of our present knowledge of the problem of ventilation, the code proposed by the Commission stands in need of considerable revision before it is drafted into law.—*C. P. Yaglou.*